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An evaluation of Hong Kong Harbor as a typhoon haven.

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AN EVALUATION OF HONG KONG HARBOR AS A TYPHOON HAVEN

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An Evaluation of Hong Kong Harbor
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Lieutenant, United States Navy
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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN METEOROLOGY

from the

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ABSTRACT

This study evaluates the harbor of Hong Kong as a typhoon haven. Characteristics of the harbor under tropical cyclone conditions, including topographical effects on the wind, storm surge and reliability of moorings and anchorages are discussed and highlighted by two case studies (Typhoon ROSE, August 1971 and Typhoon WANDA, September 1962). Problem areas to be considered if remaining in port and possible evasion procedures for ships sailing from the port are examined for tropical cyclones approaching from various directions. Tropical cyclone tracks for 87 years of data (1884-1970) for the western North Pacific Ocean are examined in order to determine the probability of threat to the port of Hong Kong. Results suggest early sortie action under threatening conditions by all Fleet units capable of evasion at sea.

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Finally, I wish to acknowledge the assistance rendered and infinite understanding shown by my wife, Carolyn, who has somehow managed to survive through 87 years of tropical cyclone tracks.

LT Donald A. MAUTNER, USN

I. INTRODUCTION

1.1 BACKGROUND

In the western North Pacific area the typhoon stands as one of the most fearsome weather elements for a ship to encounter. One of the major decisions that must often be considered by Fleet units is whether to seek or remain in the shelter of a harbor, or to take evasive action and ride out the storm at sea.

This study considers the single port of Hong Kong in terms of its characteristics to serve as a "typhoon haven." Due to the many variables involved, (i.e., topography, different directions of approach of tropical cyclones, holding action of the bottom, size and speed of the ship, etc.) it is often not possible to stamp a certain harbor simply as "safe" or "unsafe." However, the information that follows is intended to aid the local commander in making this decision. The judgement to sortie and leave a particular port is not solely determined by meteorological considerations, but also depends on other factors, such as the "measure of the harbor."

1.2 THE MEASURE OF A HARBOR

> *"The measure of a harbor is the sum total of many individual factors. It is in the extent of its shelter, depth of water at the piers, quantity and condition of its service craft and the efficiency of its port services. It is measured by the experience level of its port services officer. It is in the skill, spirit and will of his crews. It is in the emergency capability of the Ship Repair Facility to make a ship ready for sea. It is the quality of the typhoon warning service and the lead time provided the Senior Officer Present Afloat (SOPA) to make sound command decisions and to the Port Services Officer to carry out smoothly and efficiently his flexible plan of action. Finally, the measure of a harbor is knowledge of that harbor and all that it connotes in the mind of the Senior Officer Present Afloat who, by his decisions, will stamp it as a*

vital refuge to be taken or as an inanimate limited shelter to refuse as a harbor for the ships under his charge." (U. S. Fleet Weather Facility, Yokosuka, 1967)

2. THE PORT OF HONG KONG

2.1 GEOGRAPHIC LOCATION

Figure 1 shows the general location of Hong Kong in the western North Pacific. Figure 2 shows the relative orientation of the Island of Hong Kong and harbor along the China coast and the significant topographical features.

Figure 3 is a close-up of the area outlined in Figure 2, showing the harbor sea lanes, moorings, and anchorages.

2.2 THE HARBOR

The harbor of Hong Kong, located at approximately 22.3N and 114.2E, lies between the north side of Hong Kong Island and the China mainland. The harbor varies in width from one to six n mi and covers an area of 23 square n mi. The harbor and anchorage areas vary in depth from 3 to 6 fathoms, with 1 to 6 fathoms at the berths.[1] The tidal rise varies from 3.1 to 5.3 ft. Depths of approaches and entrances to the harbor[2] are given as follows (refer to Figures 2 and 3 for locations):

a.	East approach:	Tathong Channel	-- 6½ to 10 fathoms
b.	East entrance:	Lei U Mun Channel	-- 13 fathoms
c.	West approach:	West Lamma Channel	-- 4¼ to 5 fathoms
		East Lamma Channel	-- 4¼ to 10 fathoms
d.	West entrance:	Sulphur Channel	-- 4 to 14 fathoms

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[1] Port facilities relating to availability of berths, naval mooring classifications, and towage facilities are given in Appendix A.

[2] From U. S. Naval Hydrographic Office Publication #93, updated 1969.

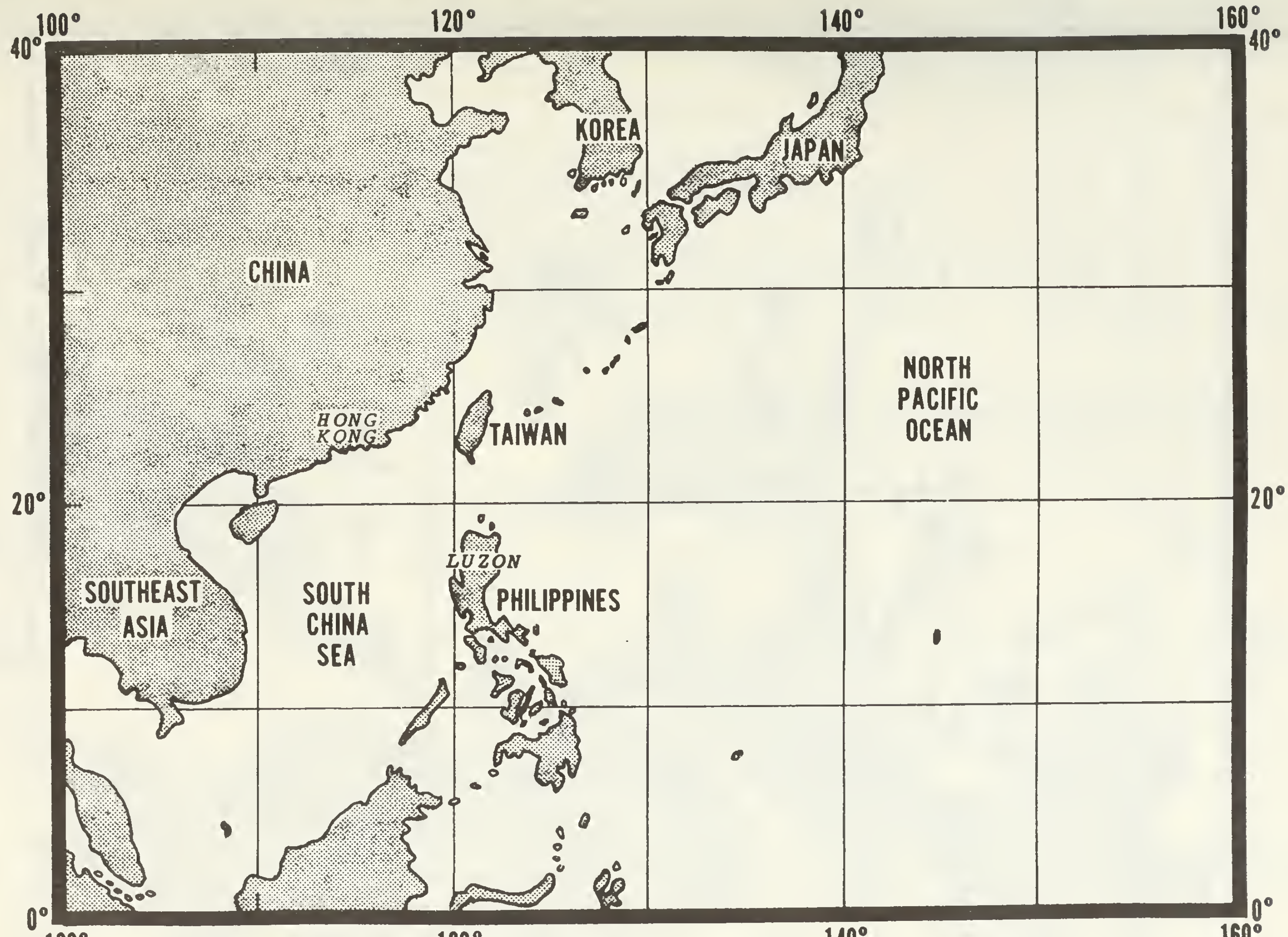

Figure 1. Location of Hong Kong in the western North Pacific Ocean.

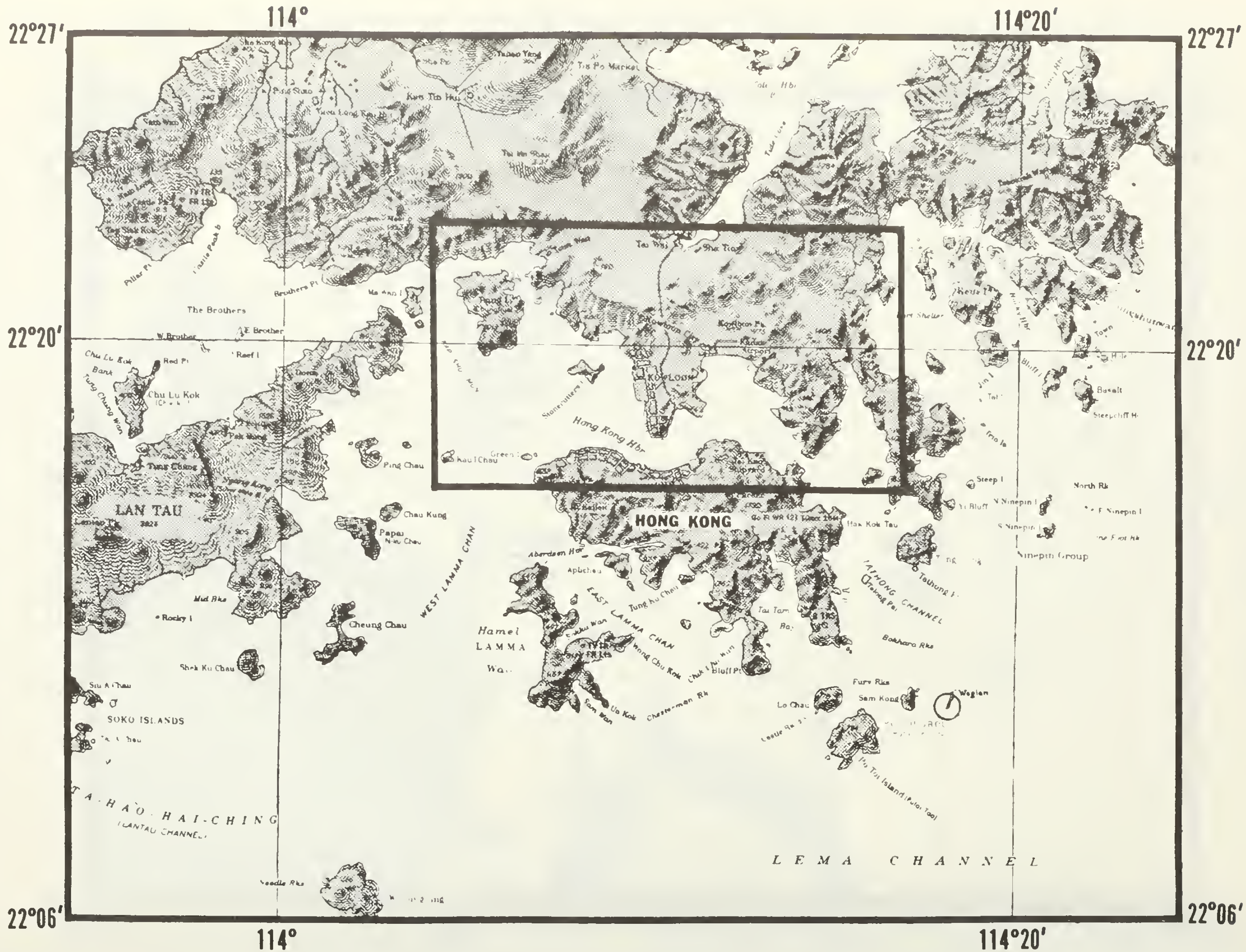

Figure 2. The Island of Hong Kong in relation to the China coast. (The outlined area of the harbor is enlarged in Figure 3.) (From DMA Hydrographic Center, 1972.)

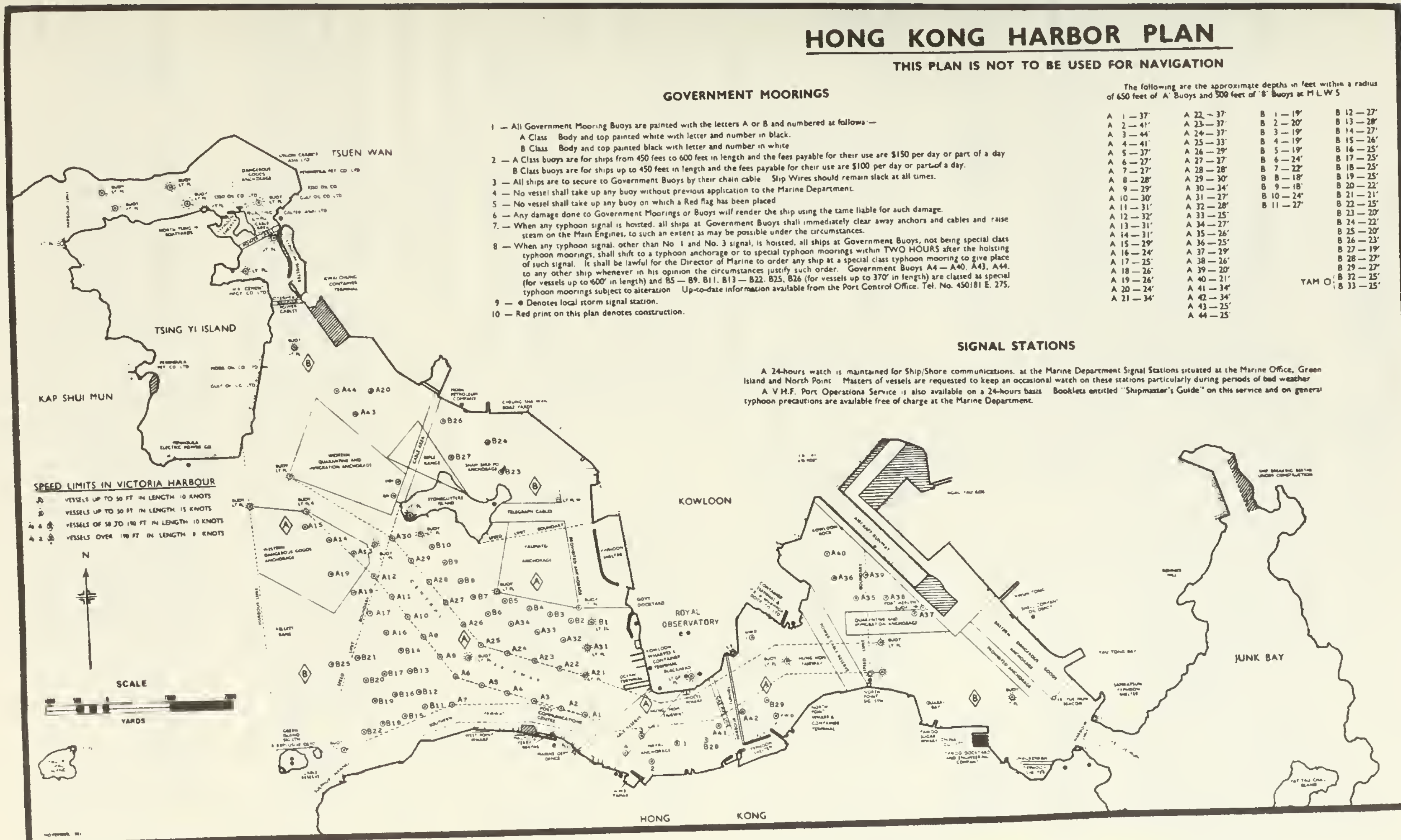

Figure 3. Hong Kong harbor. (From Government Publications Center, 1971.)

3. TROPICAL CYCLONES

3.1 TROPICAL CYCLONES IN WESTPAC

By joint international agreement, tropical cyclones in the western North Pacific Ocean (WESTPAC) area are classified according to their intensity as follows:

Tropical Depression	- maximum sustained winds not exceeding 33 kt
Tropical Storm	- maximum sustained winds between 34 and 63 kt
Typhoon	- maximum sustained winds 64 kt or greater

However, the Royal Observatory Hong Kong (ROHK), located on Kowloon (see Figure 3 for location), utilizes one further classification by subdividing "Tropical Storm" into two categories as follows (Marine Department, Hong Kong, 1970):

Tropical Storm	- maximum sustained winds between 34 and 47 kt
Severe Tropical Storm	- maximum sustained winds between 48 and 63 kt

Tropical cyclones are low pressure vortices which develop with warm-core centers, and are differentiated from mid-latitude (extratropical, cold-core) lows by their area of origin (usually in the tropics), their dynamics, and the characteristics of the surrounding air masses. The "birth" of these low pressure centers usually takes place between latitude 25N and 25S, except very near the equator. Like typical low pressure systems, the wind circulation in a tropical cyclone is counterclockwise about its center in the Northern Hemisphere and clockwise in the Southern Hemisphere.

A typhoon can be thought of as a giant "heat engine" that obtains the energy to grow and sustain itself from the warm ocean waters over which it travels. Empirical data indicates that sea-surface temperatures exceeding 26C (78.8F) allow the

initial formation of a tropical cyclone. Such sea-surface temperatures are prevalent over the warm tropical waters, hence this is usually not a limitation in low latitudes. However, if the source of energy supply is decreased or cut off (e.g., by a typhoon moving over a major land area) the system will soon weaken and die. A full fledged "super typhoon" can sustain winds of 130 kt with gusts exceeding 175 kt and such storms do occur on occasion in WESTPAC.

Tropical cyclones are largely steered by upper level winds (between 5,000 and 30,000 ft above the surface), although many other meteorological parameters must also be considered when movement is to be predicted. The general path is towards the west-northwest in the Northern Hemisphere, however, it is not uncommon for a typhoon to make an occasional "loop" in its track. "Recurvature" in the Northern Hemisphere takes place when the westward progression of the tropical cyclone begins to cease and a more northerly and finally northeasterly direction results.[1] Once the tropical cyclone or typhoon recurves into the mid-latitudes, the speed of movement usually accelerates to as much as 20 to 30 kt or greater in the stronger upper air steering flow. However, the system has a tendency to gradually weaken as it either moves over colder ocean waters or cool surface air enters the storm system.[2]

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[1]See Appendix B for monthly climatological tracks of tropical cyclones in WESTPAC which at some time were of typhoon intensity. Twenty four years of tracks were compiled (1946-1969). The often erratic nature of movement is quite obvious.

[2]Further discussion of acceleration of movement after the point of recurvature is available in a recent paper by Burroughs and Brand (1973). Riehl (1972) has also discussed the intensity of typhoons after the point of recurvature.

The average speed of movement of tropical cyclones moving into the South China Sea area (Figure 1), prior to recurvature, is approximately 10 to 11 kt. This may vary considerably, however, depending upon the individual storm.

A point to be remembered about a tropical cyclone is that it generates swell waves in all directions outward from its center. These long period swell waves can often warn of an approaching storm with heavy seas.

The sea state (combined sea and swell height)[3] in the vicinity of tropical cyclones varies as a function of a number of parameters associated with the storm, including its intensity, duration, size and movement. For example, a recent study of the state of the sea around tropical cyclones in the western North Pacific Ocean to the east of the Philippines (Brand, et al, 1973) reveals that with an average tropical storm (in the range of 34-63 kt) one can expect 12-ft seas or higher within a range of 217 n mi from the storm center, while with an intense typhoon (sustained winds greater than 100 kt) one can expect 12-ft seas or more over a 450 n mi radius from the center. It should be stressed, however, that these are averages and the actual value varies from one tropical cyclone to another.

3.2 TROPICAL CYCLONES AFFECTING HONG KONG

The "season" for tropical cyclones for Hong Kong is from June through October, although gale force winds (average wind speed 34-47 kt) associated with the passage of tropical cyclones have been recorded as early as the 19th of May and

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[3]The combined sea height is defined as the square root of the sum of the squares of "significant" sea and swell height. Sea represents wind waves and swell consists of wind generated waves which have advanced into regions of weaker or calm winds. "Significant" will be defined here as the average height of the highest one-third of the waves observed over a specified time.

as late as the 23rd of November. Tropical cyclones can and do occur at any time of the year, but the storms in the "off season" (November through May) have seldom affected the port of Hong Kong in the past.

Climatological statistics indicate that five or six tropical cyclones threaten Hong Kong each year and require the hoisting of the Number One local storm warning signal,[4] with one of these storms coming near enough to cause gale force winds (34-47 kt). On the average, once in every ten years the center of a fully developed typhoon passes sufficiently close to the harbor to provide sustained typhoon force winds (>63 kt) and cause severe damage to shipping in the harbor as well as local inland flooding. This does not, however, preclude the occurrence of such a storm during any particular year (Marine Department, Hong Kong, 1970).

If the center of a tropical cyclone passes to the south and crosses the south China coast to the west of Hong Kong, winds locally will be generally from the east or southeast with gale conditions (34-47 kt) possible for several hours, providing Hong Kong comes under the direct wind circulation of the storm. If the center of a typhoon moves northward to the east of Hong Kong, winds will be from the north to northwest and gales are less likely, unless the storm is intense or passes relatively close to Hong Kong. In addition, rainfall can be expected to be quite heavy in the former case (a typhoon passing to the west of Hong Kong), compared to relatively lighter amounts of precipitation when a typhoon passes to the east of Hong Kong.

Local warning bulletins and forecasts are issued regularly by the Royal Observatory Hong Kong (ROHK) whenever a local wind warning signal is hoisted.

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[4] Definition of Storm Signal 1: "A tropical cyclone is centered within about 400 n mi of Hong Kong and may later cause destructive winds in the colony." All Hong Kong Storm Signals are listed in Figure 45.

4. TROPICAL CYCLONE CLIMATOLOGY FOR HONG KONG

Figures 4 through 10 illustrate actual tracks of 62 typhoons and tropical storms (from 49 years of data) which gave rise to gale conditions in Hong Kong.[1] The tracks are presented for the period June through November. The broken track lines in Figures 4 through 10 illustrate typical tracks of tropical cyclones not affecting Hong Kong (see Appendix B for comparison to all tropical cyclone tracks).

Of the 62 typhoons and tropical storms considered, a total of 53 (85%) formed over the Pacific Ocean to the east of the Philippine Islands. Fifty of these 53 storms (94%) crossed a line joining Basco and Manila (Figure 4). Hence, storms crossing this line can be considered to be in a high-probability "danger belt" for giving gale conditions at Hong Kong. It should be noted, however, that tropical cyclones which develop in the South China Sea may also pose a threat to Hong Kong since these storms form at no great distance from the port and historically have shown erratic movement and looping tracks.

Figure 11 shows the positions of tropical cyclone centers when first and last strong winds ($\geq$22 kt) occurred at the Royal Observatory Hong Kong (ROHK) on Kowloon (Figure 3). Data from 1937-1964 (28 years) was used in obtaining Figure 11. Similarly, Figure 12 shows the positions of tropical cyclones when the first and last gales (winds $\geq$34 kt) occurred at the Royal Observatory. In both figures the "circle" ("O") symbolizes the position of the tropical cyclone when strong winds (Figure 11), or gale force winds (Figure 12), began and the "arrow ("→") the position when the winds ended.

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[1]The tracks used were taken from years: 1884-1896, 1905-1940 and 1946-1949.

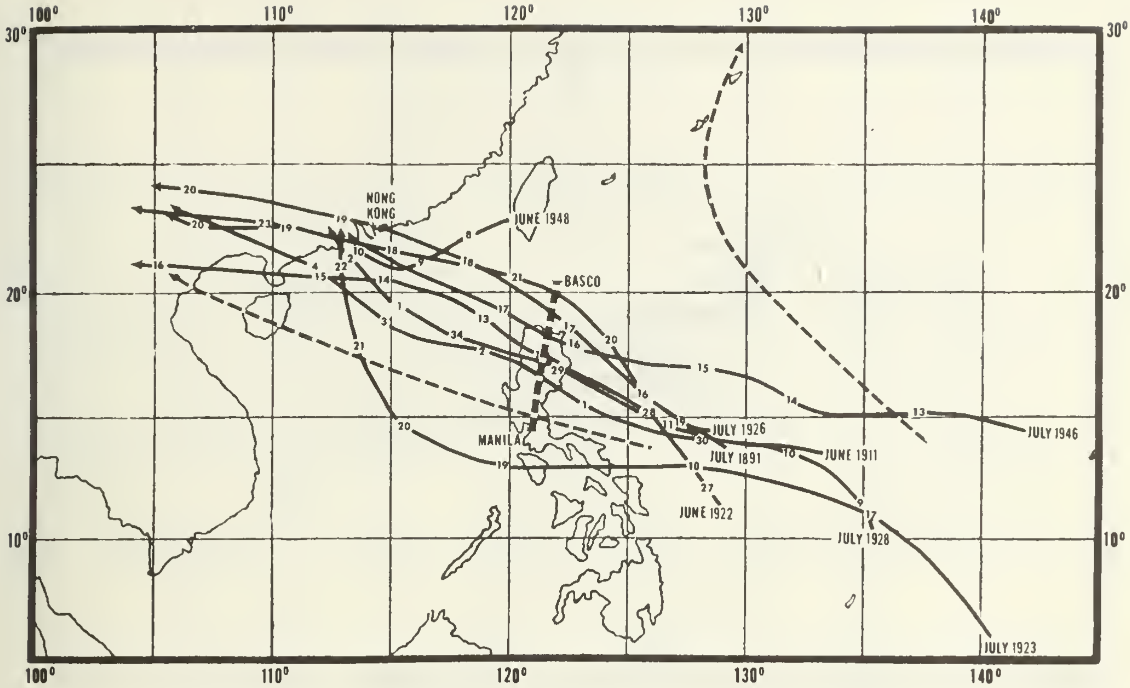

Figure 4. Tracks of typhoons and tropical storms associated with gales in Hong Kong; June and early July. (From Heywood, 1950.)

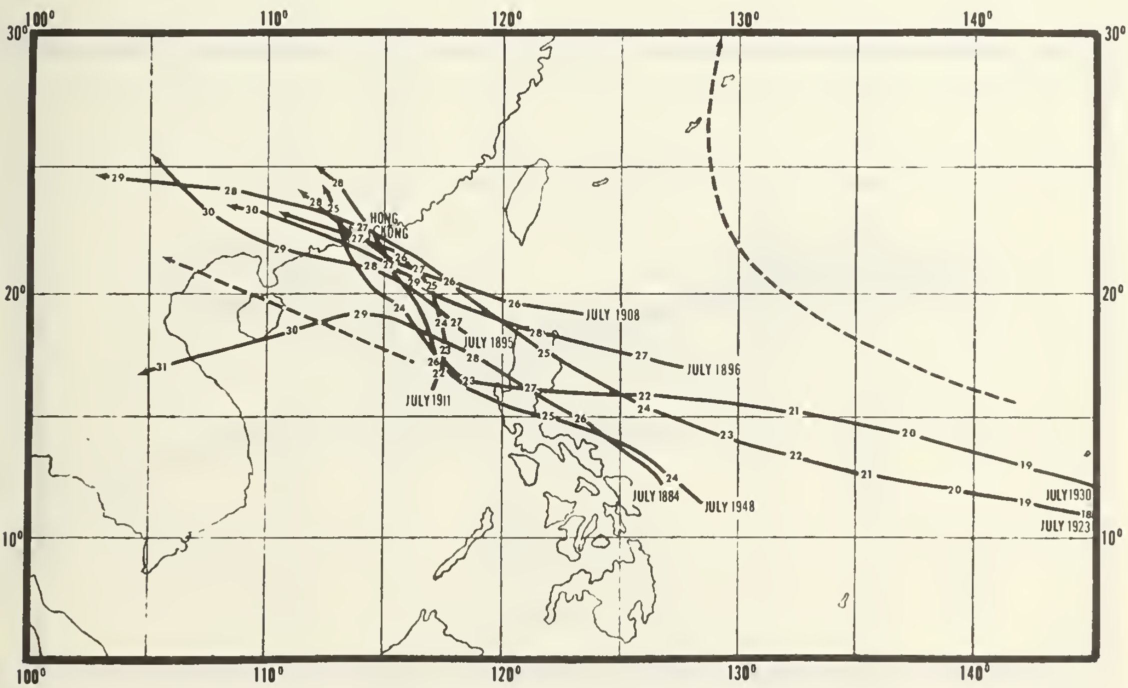

Figure 5. Tracks of typhoons and tropical storms associated with gales in Hong Kong; late July. (From Heywood, 1950.)

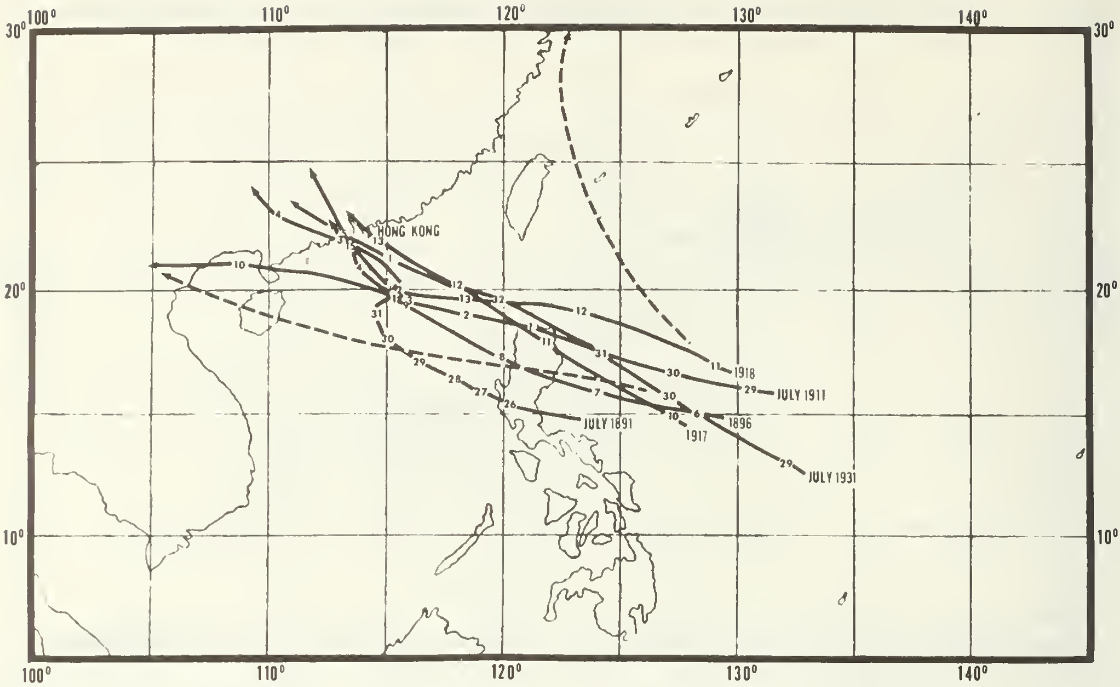

Figure 6. Tracks of typhoons and tropical storms associated with gales in Hong Kong; early August. (From Heywood, 1950.)

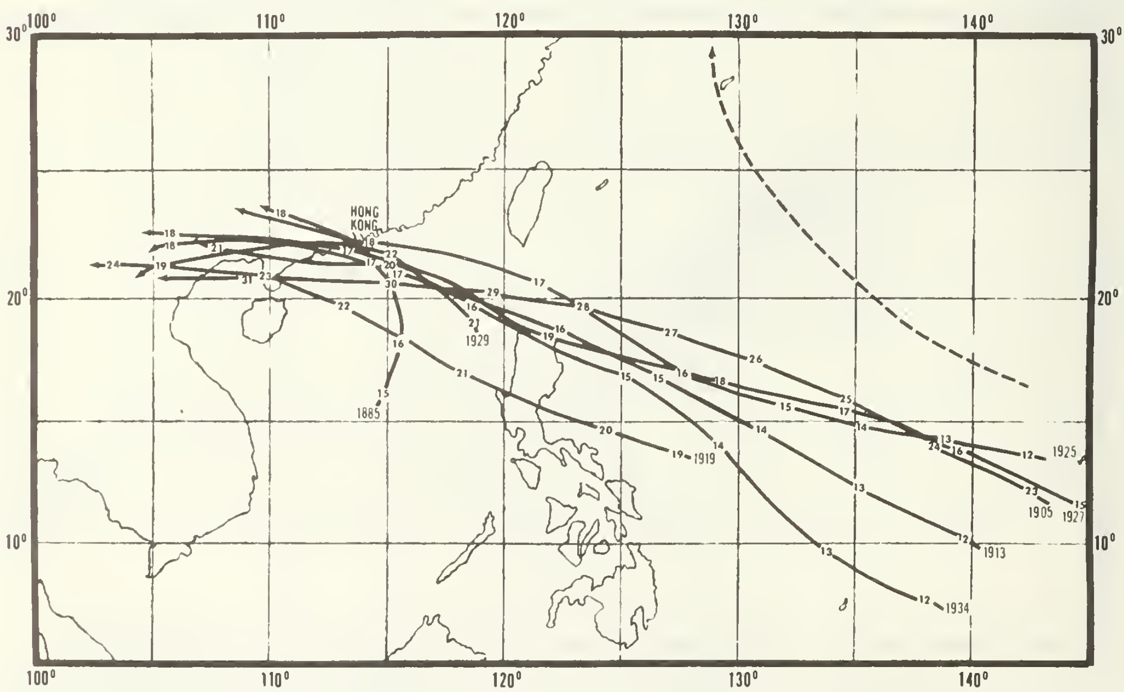

Figure 7. Tracks of typhoons and tropical storms associated with gales in Hong Kong; late August. (From Heywood, 1950.)

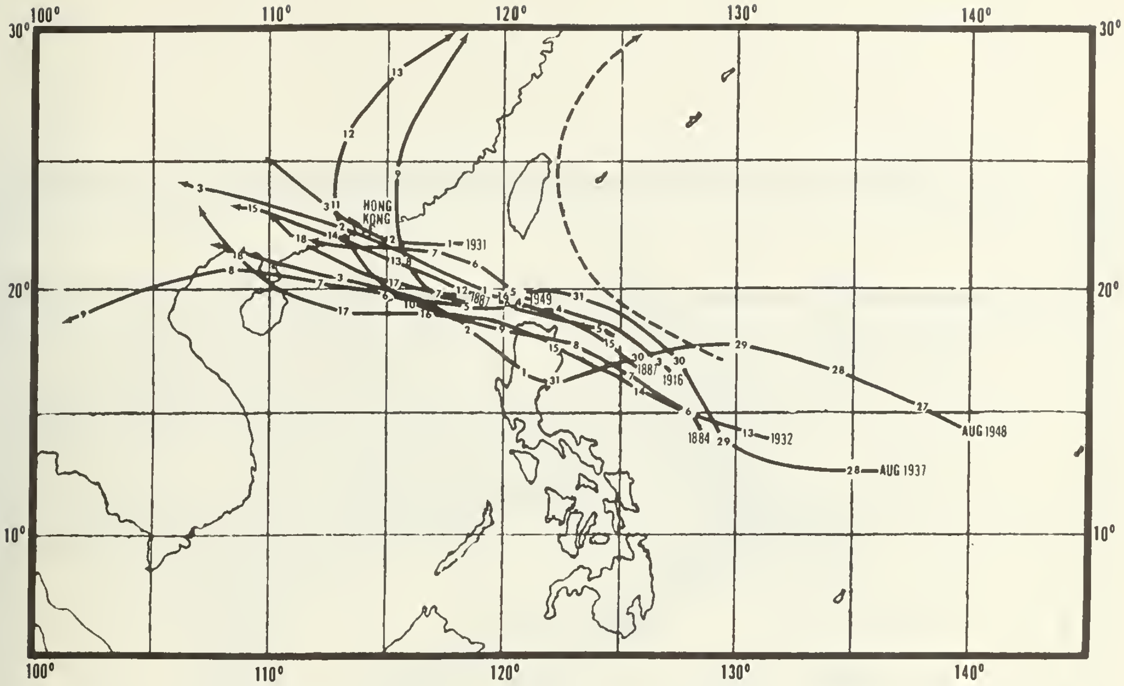

Figure 8. Tracks of typhoons and tropical storms associated with gales in Hong Kong; early September. (From Heywood, 1950.)

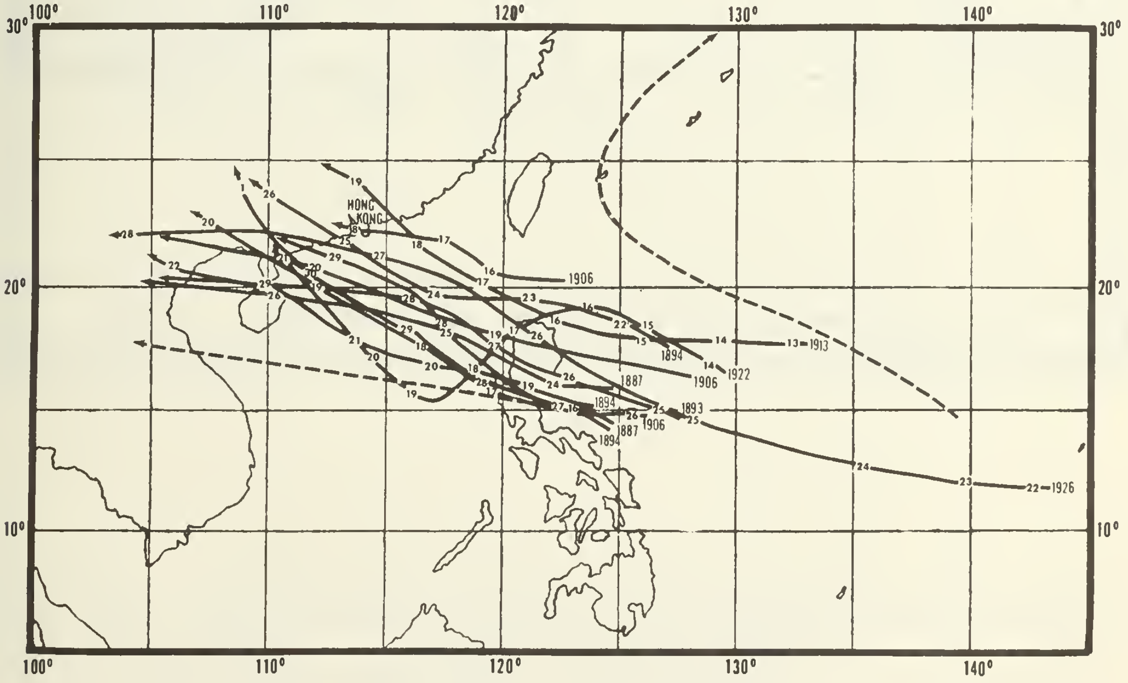

Figure 9. Tracks of typhoons and tropical storms associated with gales in Hong Kong; late September. (From Heywood, 1950.)

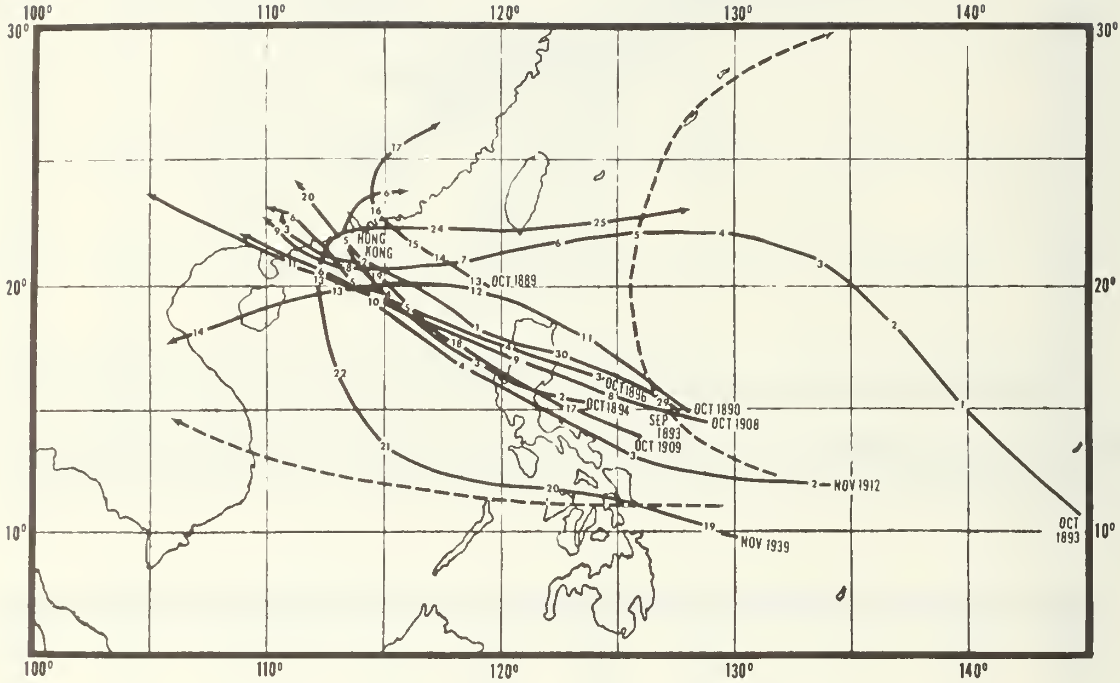

Figure 10. Tracks of typhoons and tropical storms associated with gales in Hong Kong; October and November. (From Heywood, 1950.)

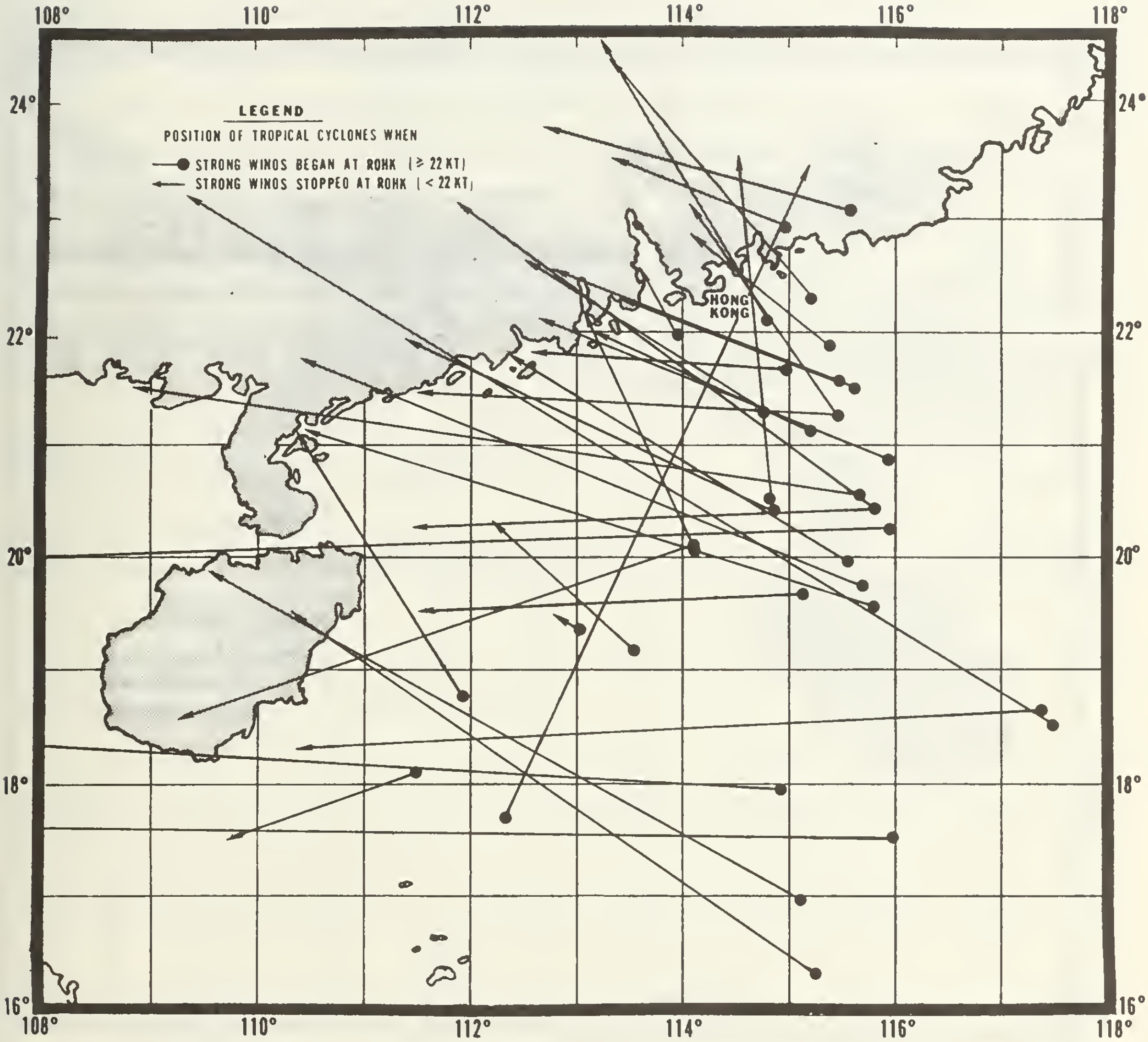

Figure 11. Positions of tropical cyclone centers when first and last strong winds occurred at the Royal Observatory, Hong Kong (ROHK). Based on data from 1937 to 1964. (From Royal Observatory Hong Kong, unpublished.)

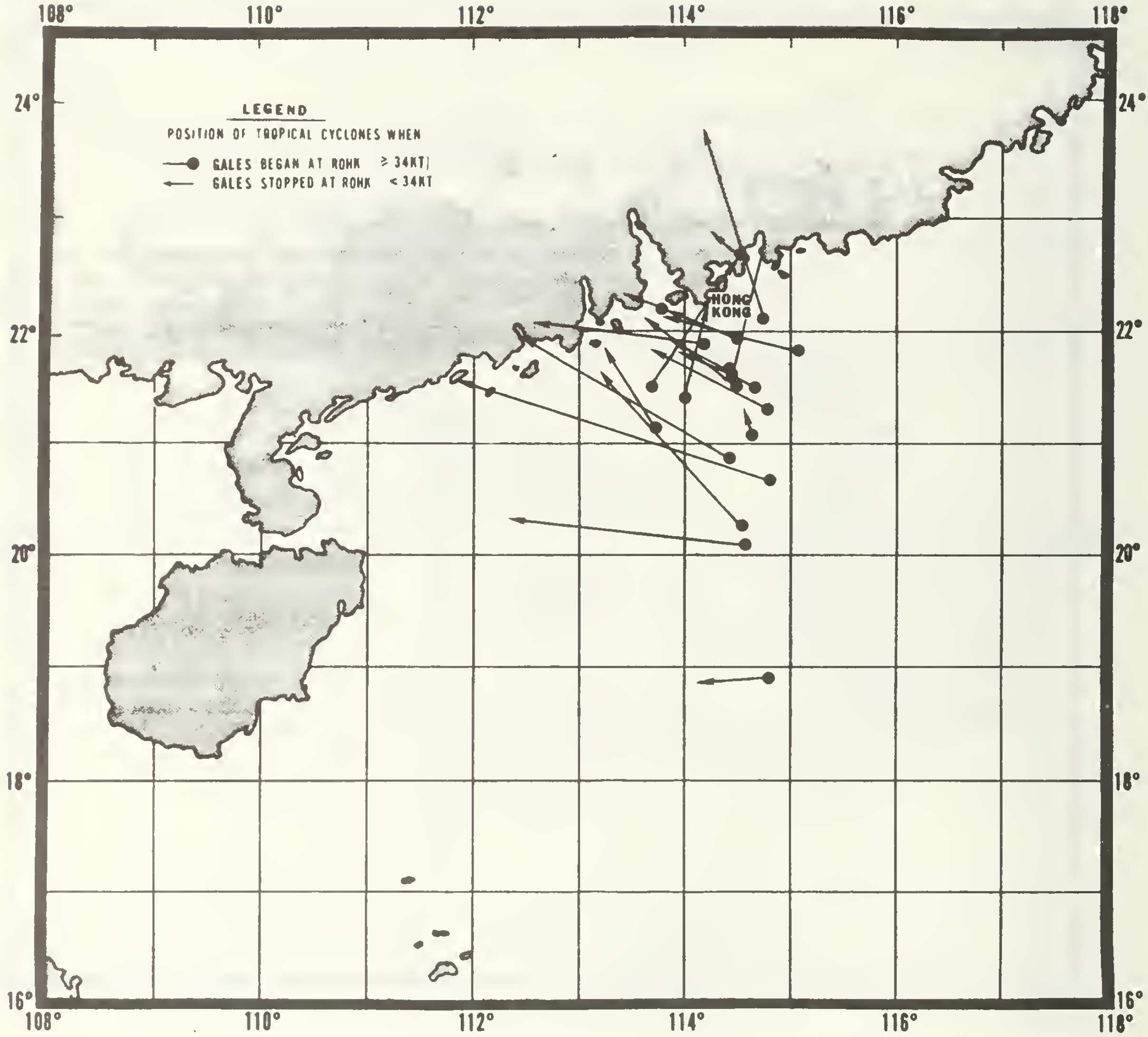

Figure 12. Positions of tropical cyclone centers when first and last gale force winds occurred at the Royal Observatory, Hong Kong (ROHK). Based on data from 1936 to 1964. (From Royal Observatory Hong Kong, unpublished.)

For the most part, the onset of strong winds ($\geq$22 kt) occurs as the tropical cyclones cross 116E moving on a general westerly or northwesterly track. The onset of gale force winds ($\geq$34 kt) occurs as the storms cross 115E and is generally associated with the more northerly-tracking tropical cyclones north of 20N.

Figure 13 shows the frequency distribution for the number of typhoons and tropical storms which created gale conditions in Hong Kong. These are grouped into 5-day periods and are based on 62 years of data (1884-1941; 1946-1949). Note the overwhelming frequency of occurrence in the months of July, August, and September.

Figure 14 shows the average direction of approach to Hong Kong of the 62 typhoons and tropical storms considered previously (Figures 4 through 10) and the percentage frequency of these approaches for each octant of the compass. Approximately 95% of these tropical cyclones approached Hong Kong from the east through the south. The length of each line is proportional to the number of occasions on which the cyclones approached from a given octant.

Table 1 relates the mean distance and bearing of tropical cyclones from Hong Kong when strong winds ($\geq$22 kt) prevailed at the Royal Observatory Hong Kong (ROHK) (see Figure 3) and winds $\geq$28 kt prevailed at Waglan Island (see Figure 15). The mean positions of the tropical cyclone centers were computed from 32 years of data (1936-1967).

Figure 16 is a graphical representation of Table 1. Note that tropical cyclones passing or approaching from the south caused strong winds at Hong Kong and Waglan Island sooner than from any other direction of approach. In addition, the stronger winds recorded even <u>earlier</u> at Waglan Island demonstrate the effect of the topography in causing decreased winds inland at ROHK compared to the open ocean surrounding Waglan Island. The large variation between

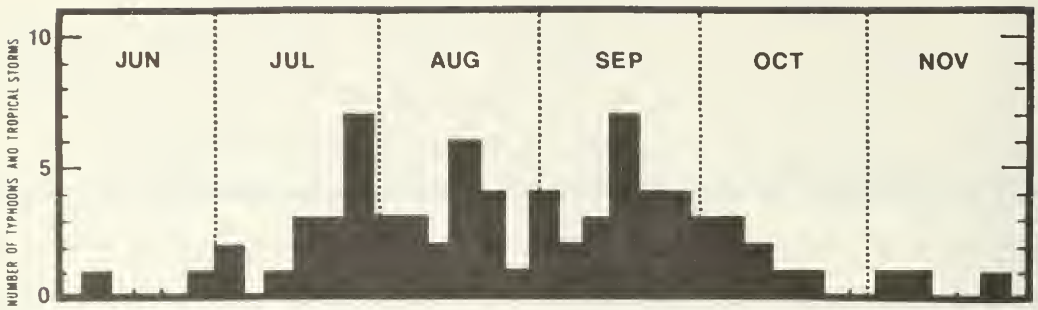

Figure 13. Frequency distribution of the number of typhoons or tropical storms giving gale force conditions to Hong Kong for 5-day periods. Based on 62 years of data. (From Heywood, 1950.)

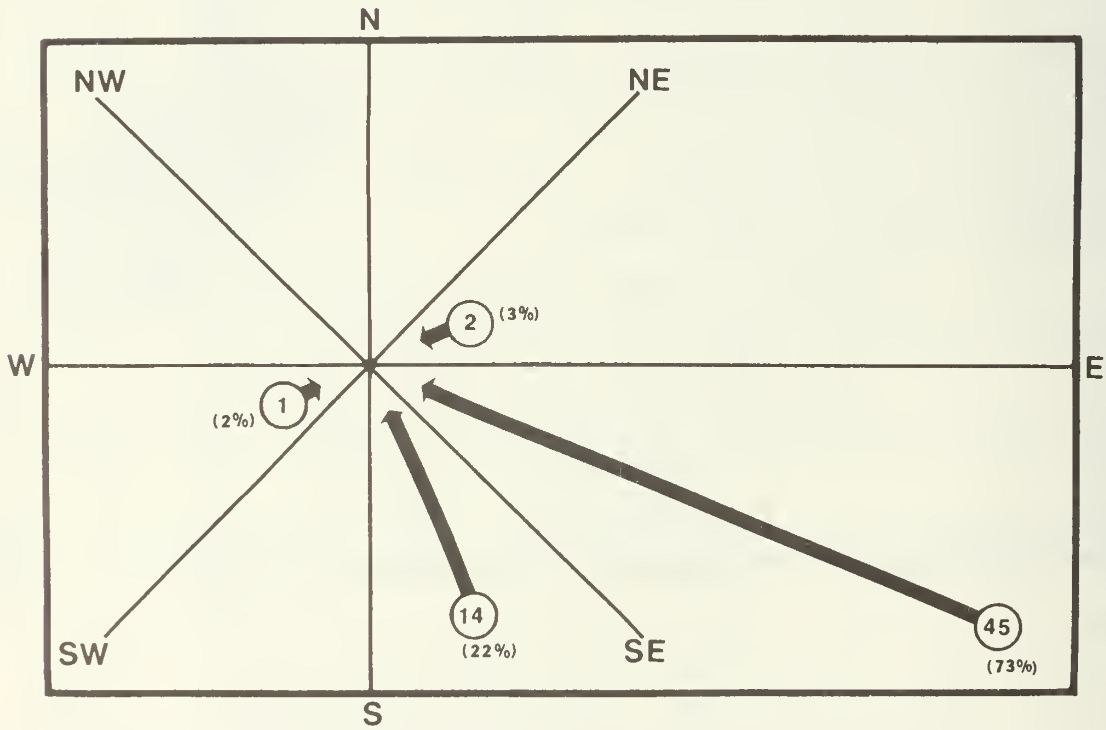

Figure 14. Direction of approach to Hong Kong of typhoons and tropical storms. (The length of each line is proportional to the number of occasions on which typhoons and tropical storms approached from each octant of the compass.) (From Heywood, 1950.)

Table 1. Mean distance of tropical cyclones when strong winds were first recorded at the Royal Observatory and Waglan Island (from ROHK, Unpublished).

Bearing of Center of Storm from HK	First Strong Winds at	
	Royal Observatory (≥22 kt)	Waglan Island (≥28 kt)
080° - 100	80 n mi	210 n mi
110° - 120	75 n mi	208 n mi
130° - 140	152 n mi	200 n mi
150° - 160	169 n mi	228 n mi
170° - 190	242 n mi	287 n mi
200° - 210	231 n mi	-

Waglan and ROHK for the commencement of strong winds from tropical cyclones bearing to the east of Hong Kong additionally demonstrates the role of topography in delaying the onset of the strong winds at ROHK.

Sea waves at Waglan Island should be of great interest to ships considering sortie action from Hong Kong when the harbor is being threatened by a tropical cyclone.[2] Since Waglan is located at the eastern approach to the harbor, but surrounded by open ocean, a great deal of insight can be obtained concerning rapidly increasing sea heights at the entrance to the harbor when a tropical cyclone threatens the port. A problem more peculiar to Hong Kong than many other ports in WESTPAC is the rapid building of seas at the entrance to the harbor. Adequate time must be allowed to clear the harbor in order to avoid these high seas and gain

[2]Currently, R. F. Apps and T. Y. Chen of the Royal Observatory, Hong Kong, are preparing a summary of "Sea Waves at Waglan Island." Preliminary data has been collected and is currently being analyzed. Although the summary is in rough draft form, significant figures have been forwarded from ROHK for inclusion in this study.

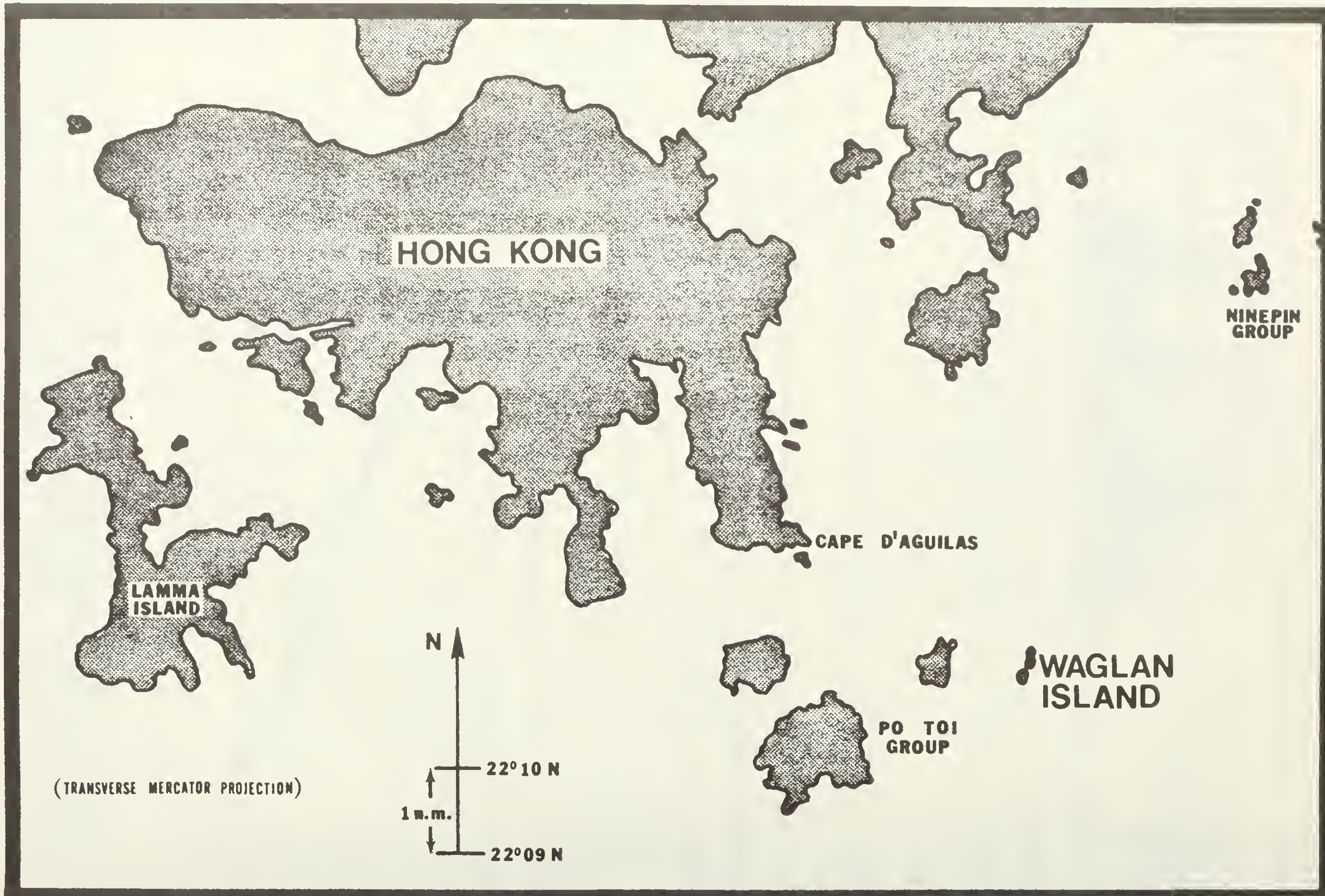

Figure 15. Location of Waglan Island with respect to Hong Kong. (From Cuming, 1967.)

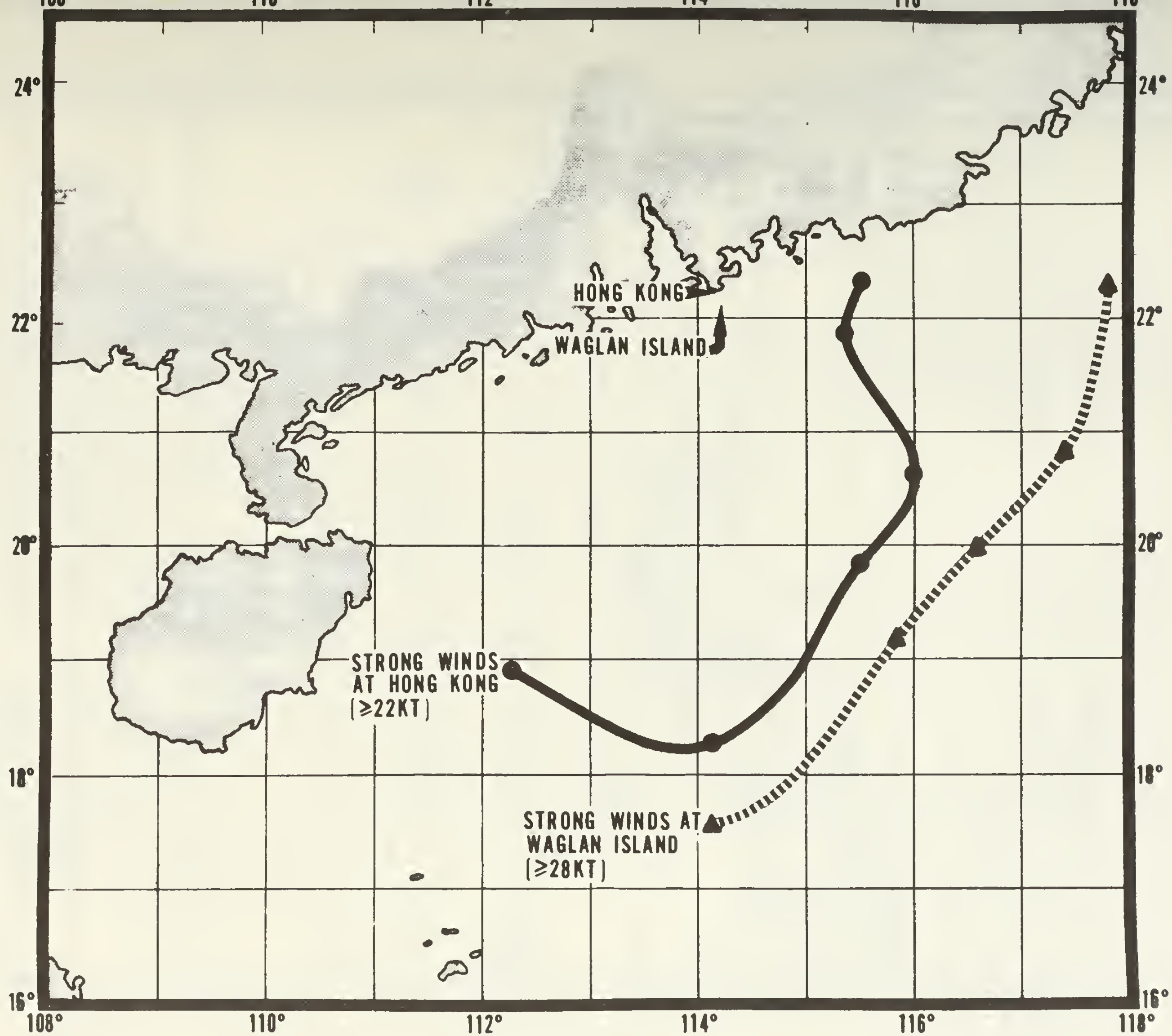

Figure 16. Graphical interpretation of Table 1, showing bearing and mean distance of tropical cyclone centers which gave rise to first reported strong winds at the Royal Observatory, Hong Kong (solid line) and at Waglan Island (dashed line).

maneuvering room in the open ocean. Figures 17 through 22 represent observed maximum wave heights off Waglan Island during the passage of tropical cyclones in the period 1959-1971. The values in each 2° latitude/longitude area relate the maximum wave heights (average maximum height of all observations and greatest single maximum height of all observations)[3] recorded at Waglan Island when a tropical cyclone was centered in that area. Tropical cyclones affecting Hong Kong were divided into three categories:

Group 1 - Those tropical cyclones passing to the south of Hong Kong with a west or west-northwest movement

Group 2 - Those tropical cyclones striking the China coast to the east of Hong Kong with a west or west-northwest movement

Group 3 - Those tropical cyclones passing to either side of Hong Kong with a northward movement

Additionally, each group was divided into two categories of intensity of the tropical cyclones:

Category 1 (more intense tropical cyclones) - all typhoons and severe tropical storms

Category 2 (less intense tropical cyclones) - all tropical storms and tropical depressions

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[3]Significant wave height (H_s or $H_{1/3}$) which represents the average of the highest 1/3 of the observed waves can be obtained approximately from the relationship: $H_s = \frac{H_{MAX}}{1.87}$, where H_{MAX} is the average maximum wave height (the bottom number in each box in Figures 17 through 22) (U. S. Naval Oceanographic Office, 1966).

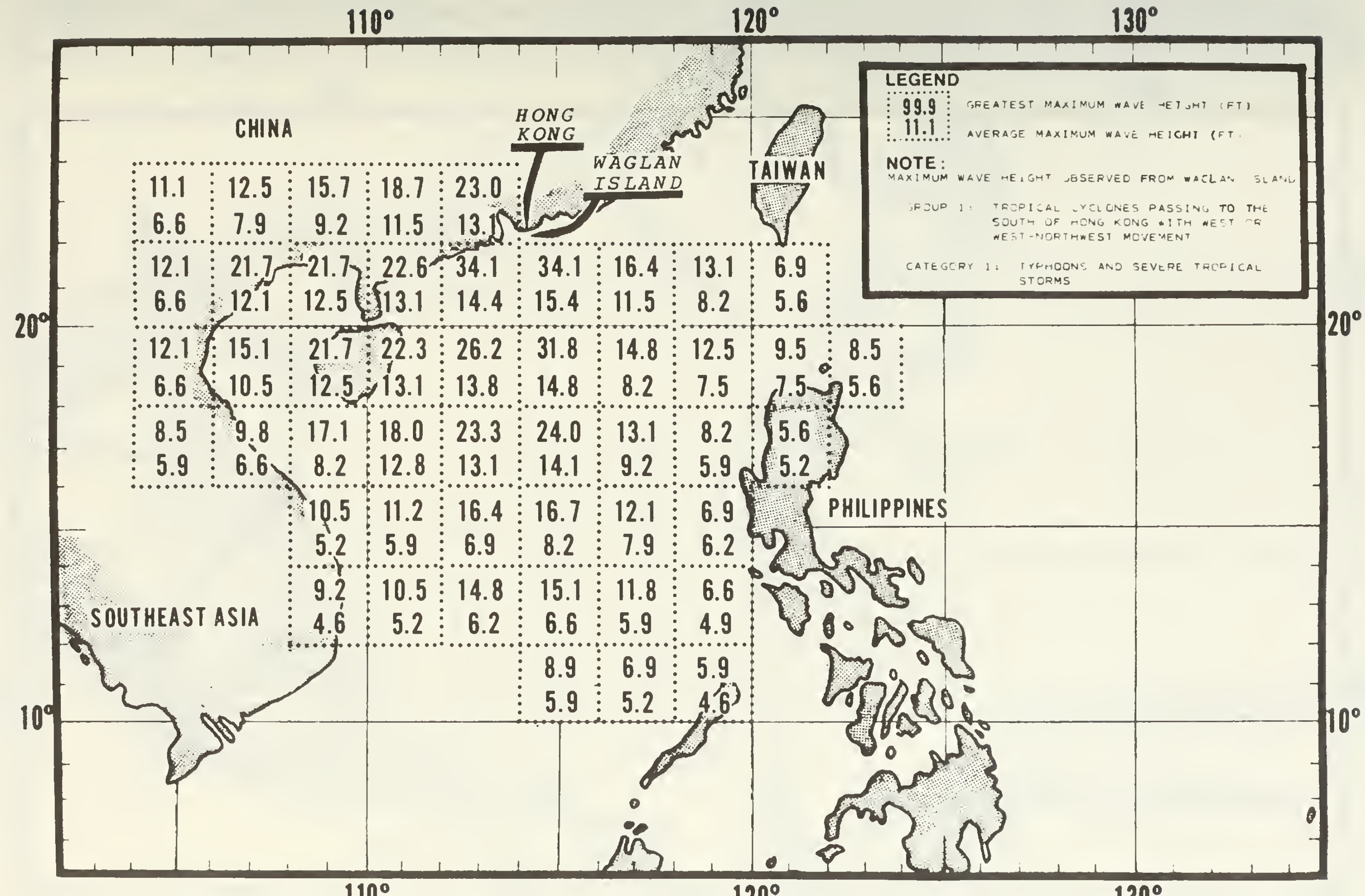

Figure 17. Maximum wave heights observed from Waglan Island for typhoons and severe tropical storms passing to the south of Hong Kong with west or west-northwest movement. (Observed when the storms were centered in the 2° latitude/longitude area.) (From Apps and Chen, unpublished.)

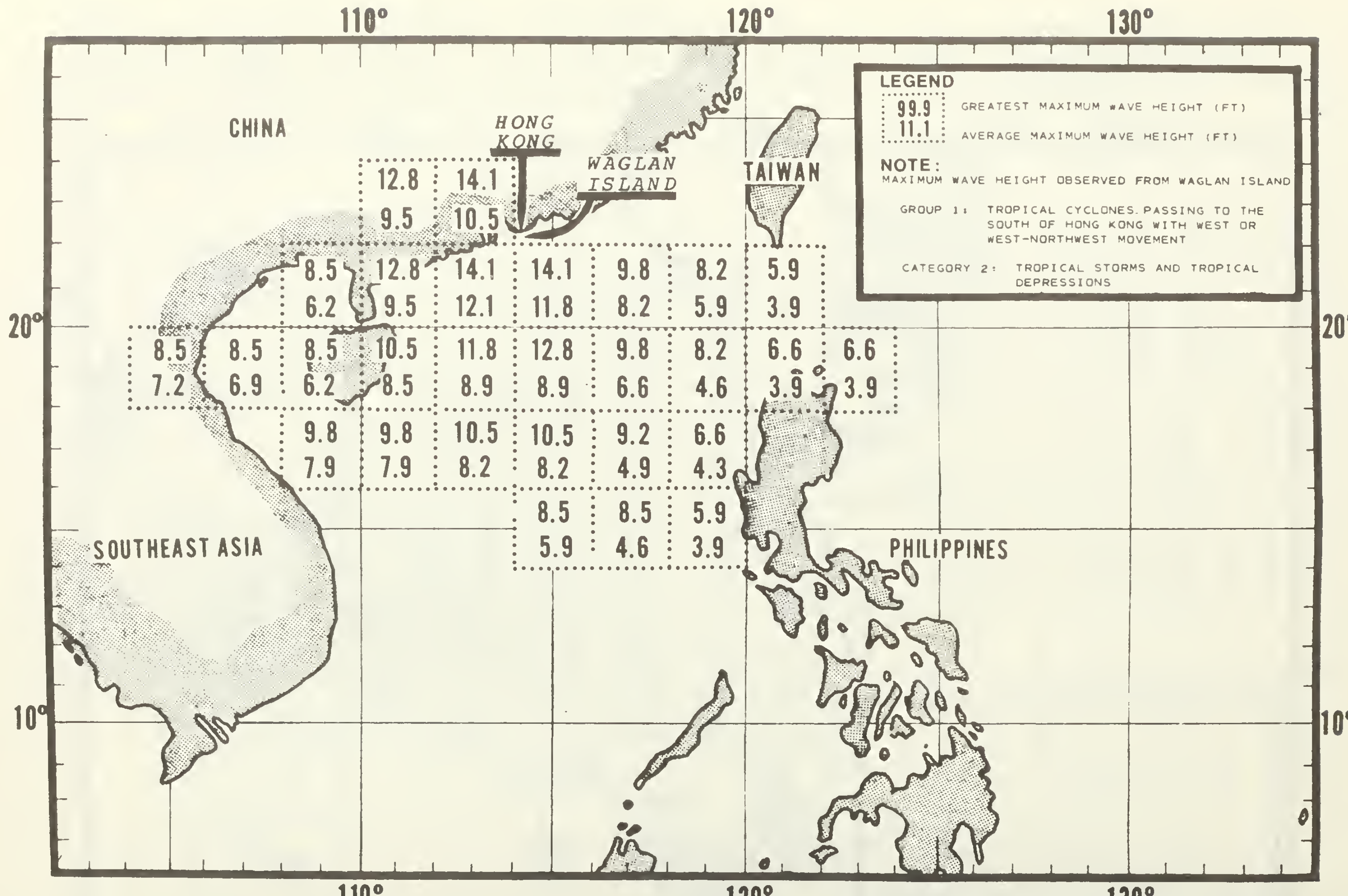

Figure 18. Maximum wave heights observed from Waglan Island for tropical storms and tropical depressions passing to the south of Hong Kong with west or west-northwest movement. (Observed when the storms were centered in the 2° latitude/longitude area.) (From Apps and Chen, unpublished.)

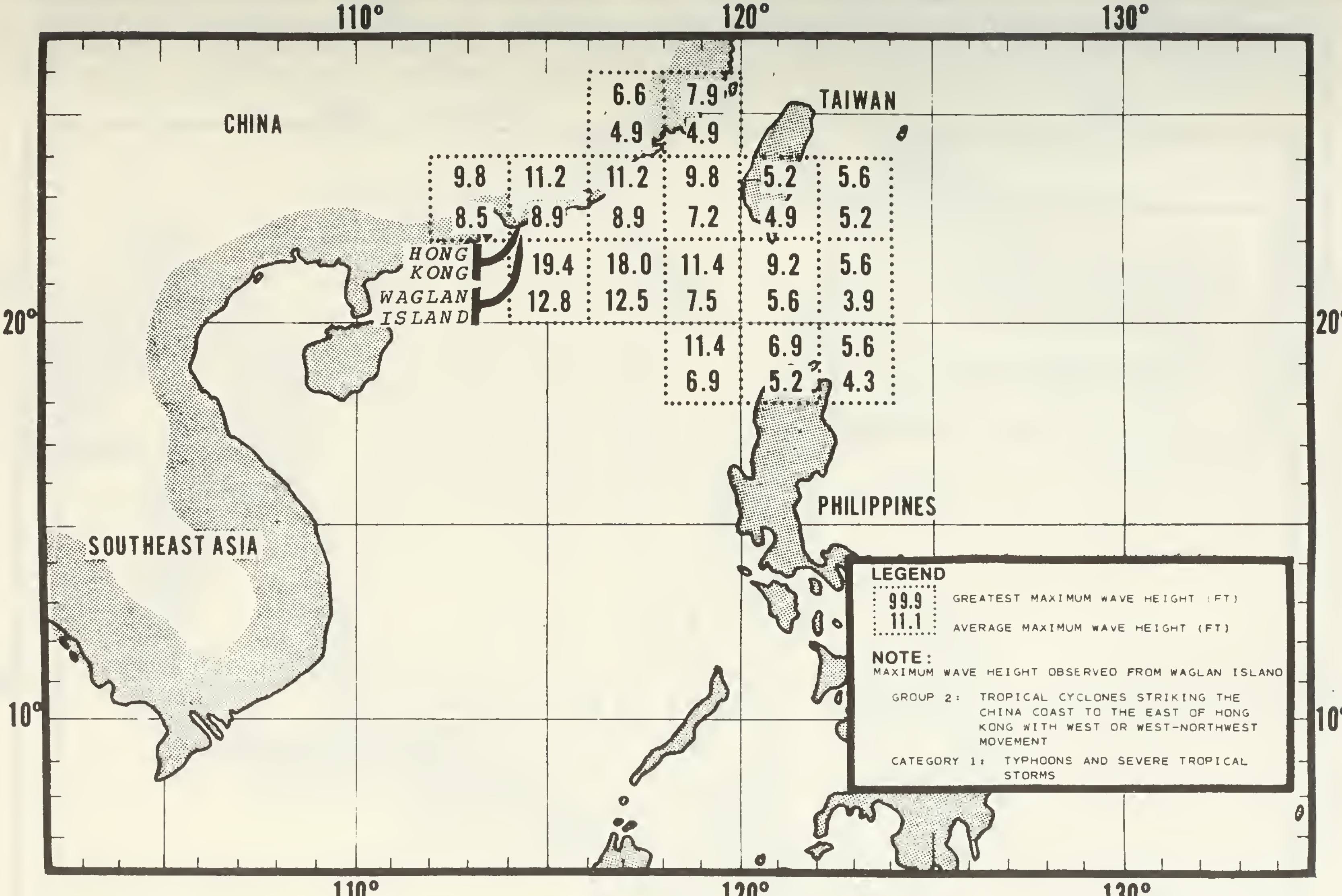

Figure 19. Maximum wave heights observed from Waglan Island for typhoons and severe tropical storms striking the China coast to the east of Hong Kong with west or west-northwest movement. (Observed when the storms were centered in the 2° latitude/longitude area.) (From Apps and Chen, unpublished.)

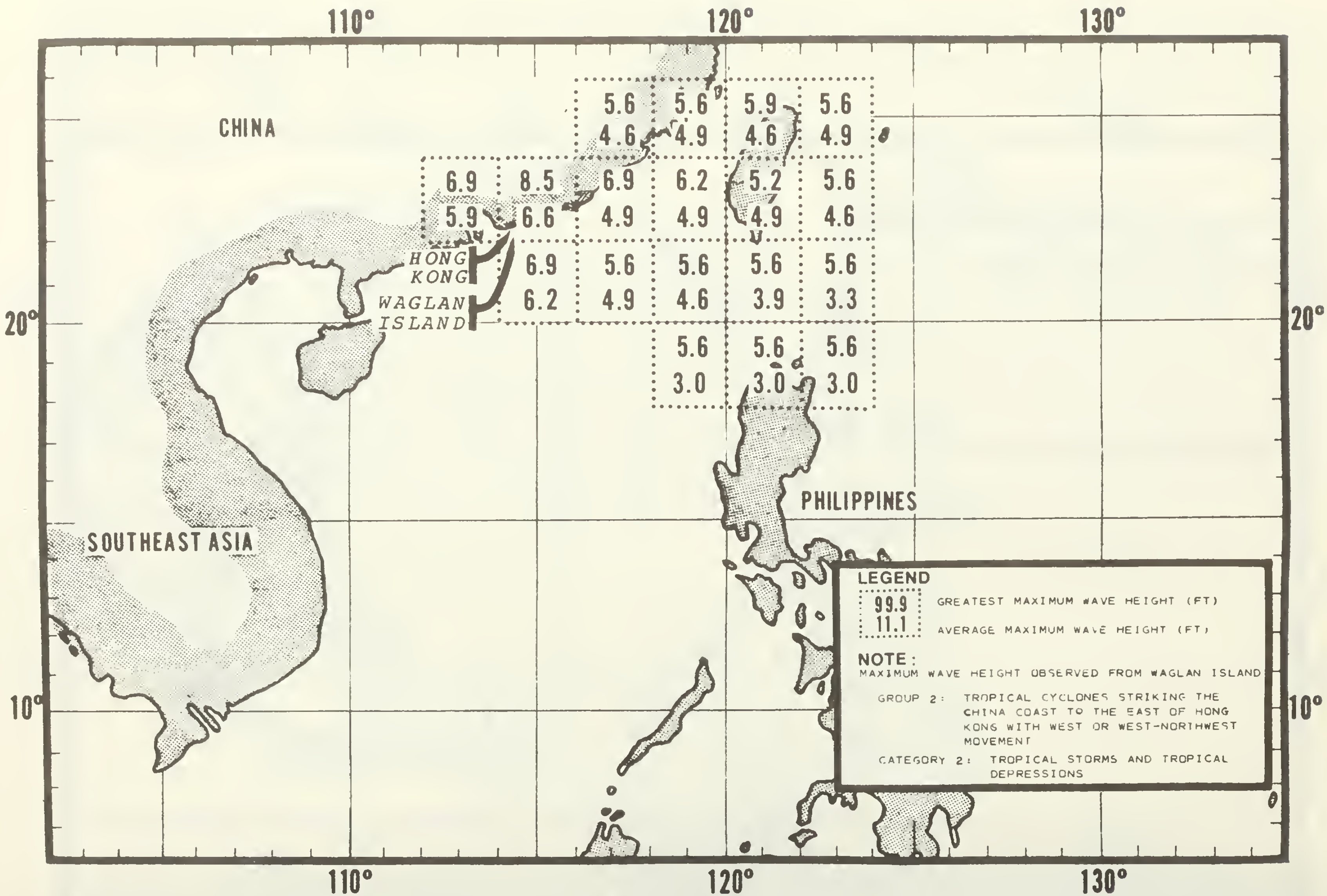

Figure 20. Maximum wave heights observed from Waglan Island for tropical storms and tropical depressions striking the China coast to the east of Hong Kong with west or west-northwest movement. (Observed when the storms were centered in the 2° latitude/longitude area.) (From Apps and Chen, unpublished.)

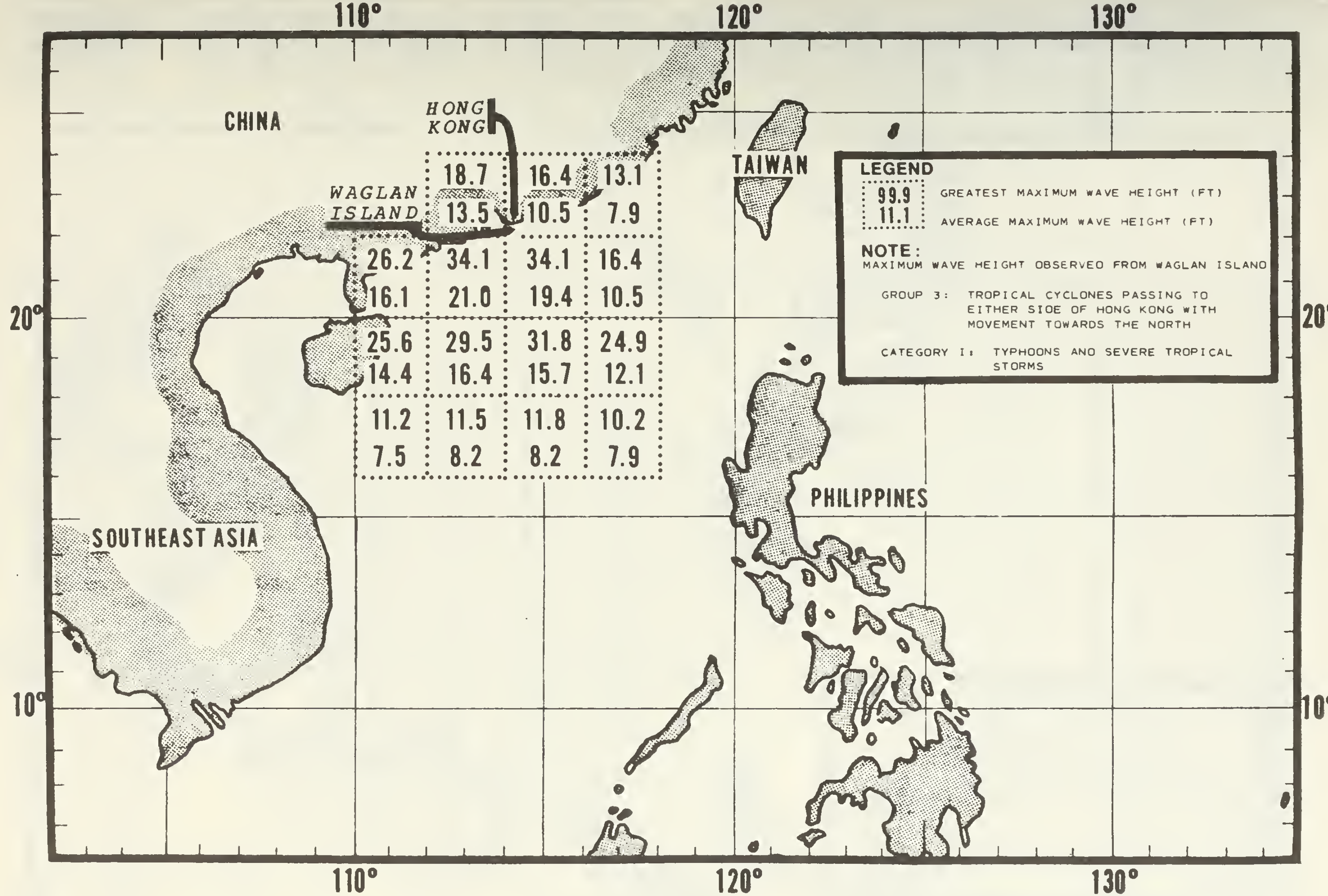

Figure 21. Maximum wave heights observed from Waglan Island for typhoons and severe tropical storms passing to the east or west of Hong Kong with northward movement. (Observed when the storms were centered in the 2° latitude/longitude area.) (From Apps and Chen, unpublished.)

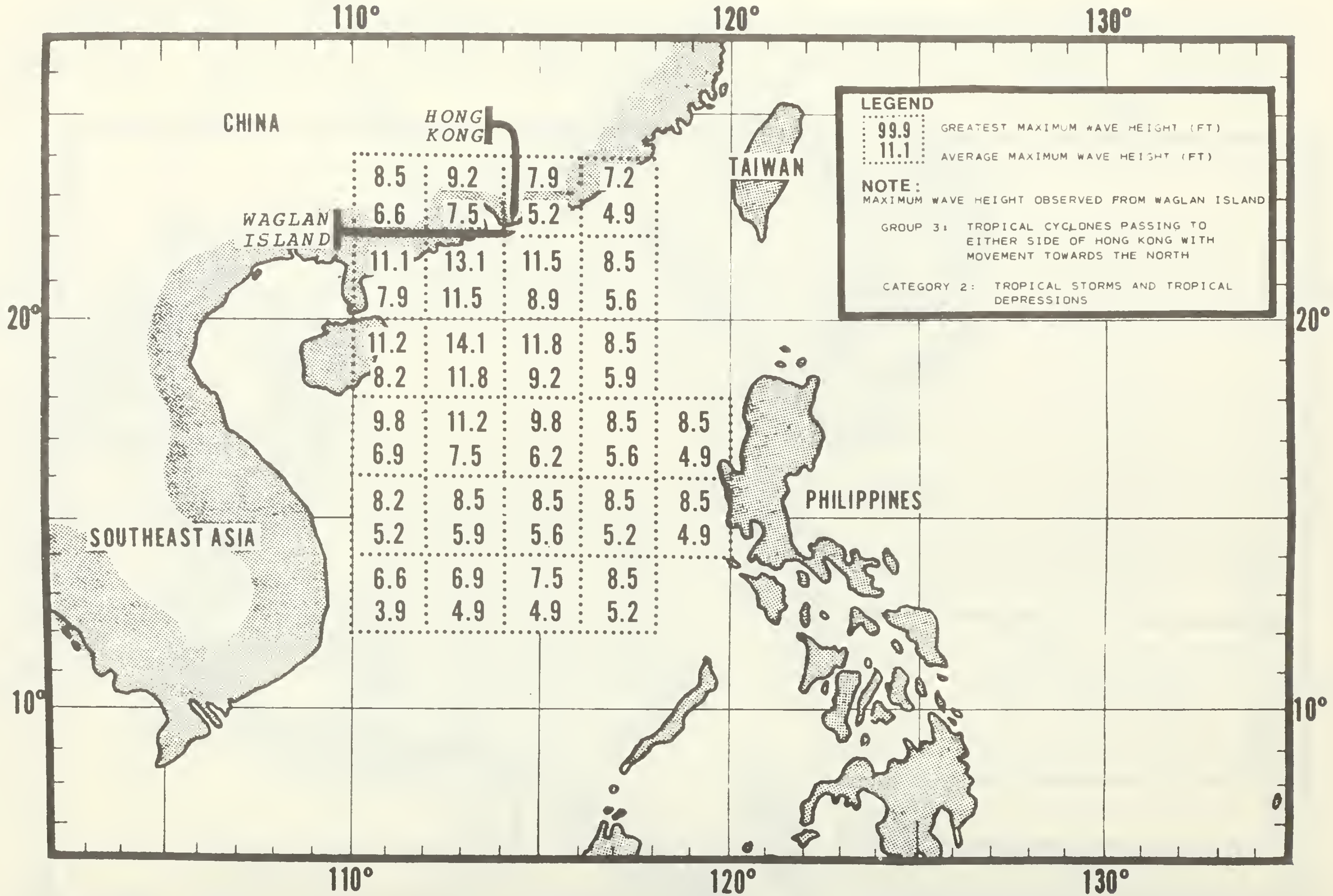

Figure 22. Maximum wave heights observed from Waglan Island for tropical storms and tropical depressions passing to the east or west of Hong Kong with northward movement. (Observed when the storms were centered in the 2° latitude/longitude area.) (From Apps and Chen, unpublished.)

Figures 17 through 22 provide a means for determining the maximum wave heights to be anticipated and when to expect these heights at the approach to the harbor. Determining these heights from the figures requires only the tropical cyclone forecast track and position relative to Hong Kong (Group 1, 2, or 3) and the relative intensity of the storm (Category 1 or 2).

There are significantly different local effects on the harbor for tropical cyclone centers passing to the west of Hong Kong as opposed to those centers passing to the east. In order to determine the probability of a tropical cyclone in the Philippine Sea or South China Sea affecting Hong Kong and its surrounding region at some future time, 87 years of tropical cyclones were examined.

Figures 23 through 29 represent a statistical summary of the 87 years (1884-1970) of tropical cyclone tracks (Chin, 1972). The tracks were compiled into monthly summaries (May-November) by tallying the number of tropical cyclones that passed through each 3° latitude/longitude area for each month over the 87-year period.[4] This tally number for the month is printed at the top of each area (defined as "N"). To analyze the tracks which came close to Hong Kong, a line tangent to the China coast, through Hong Kong, was selected (oriented east-northeast to west-southwest). A radius of 3° latitude (180 n mi) was chosen for the semicircle as is shown in Figures 23 through 29. The percentage of tropical cyclones (defined as "RAD") that passed through the box and also passed within the 180 n mi semicircle is given at the bottom

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[4]Since the original tracks by Chin (1972) were compiled for 5-day periods, exact calendar months could not be obtained from the data; however, each month was adjusted as close to the actual calendar month as possible.

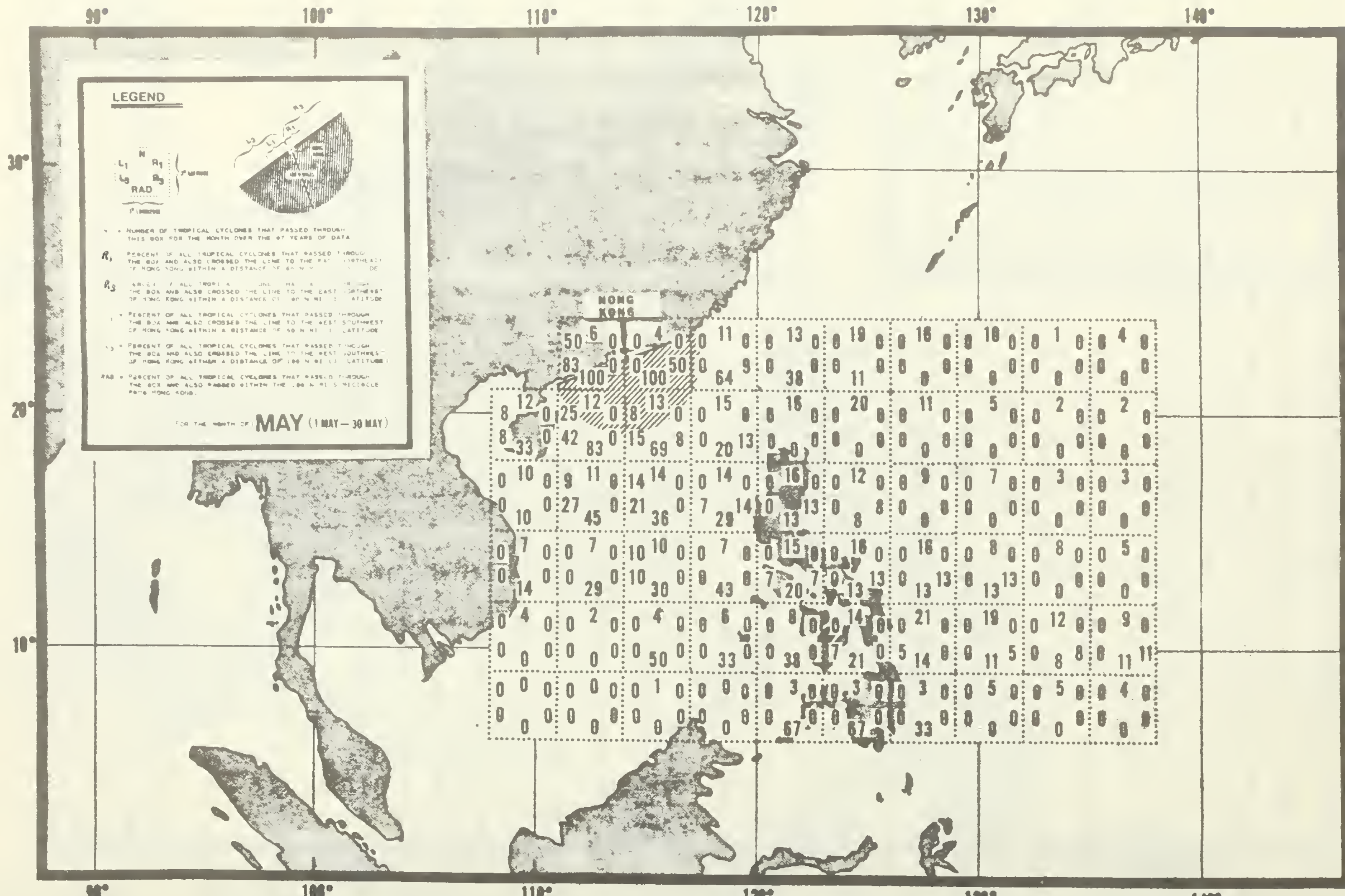

Figure 23. Statistical summary of tropical cyclone tracks that passed within a specified distance from Hong Kong for the month of May. (Based on 87 years of data.)

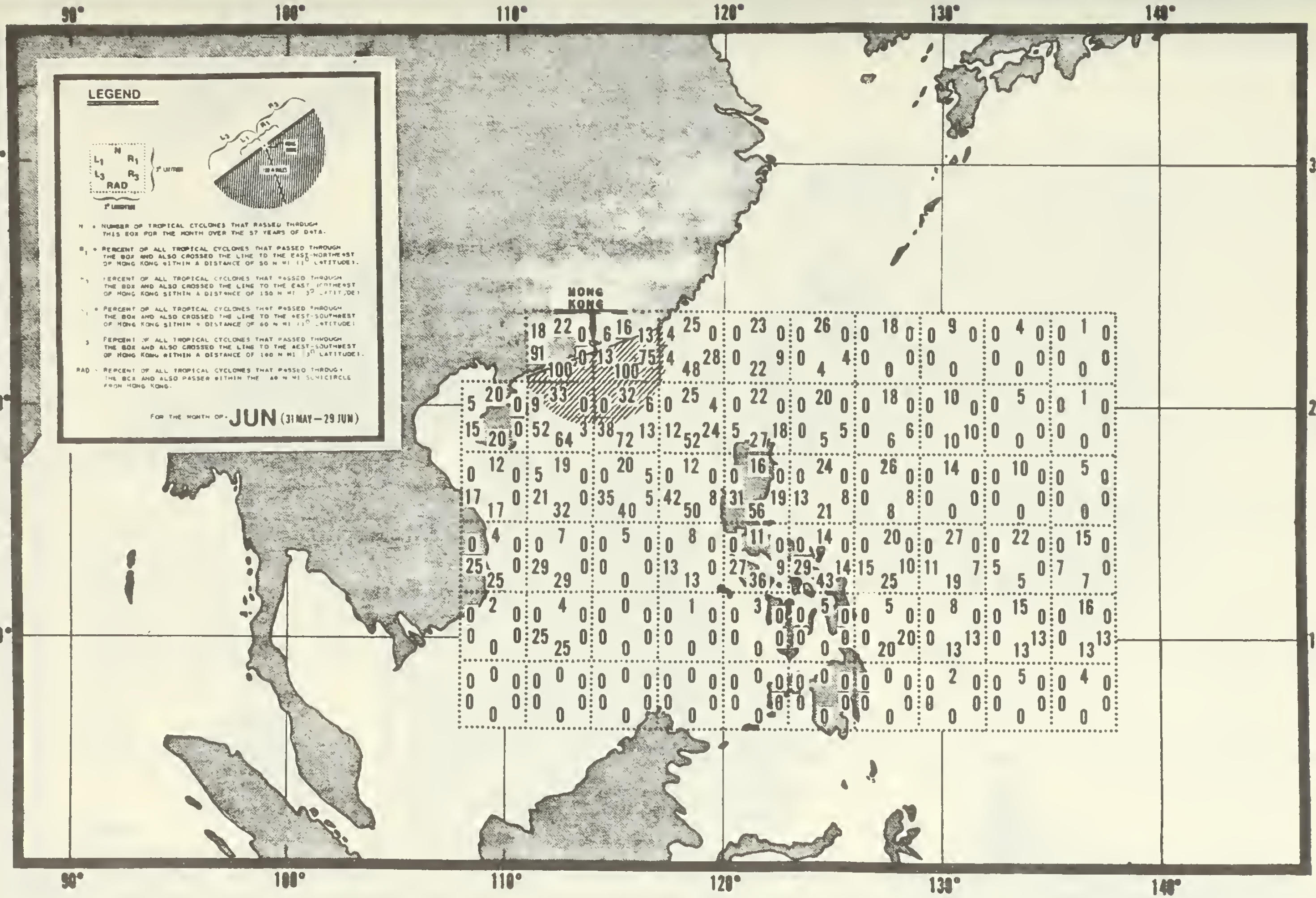

Figure 24. Statistical summary of tropical cyclone tracks that passed within a specified distance from Hong Kong for the month of June. (Based on 87 years of data.)

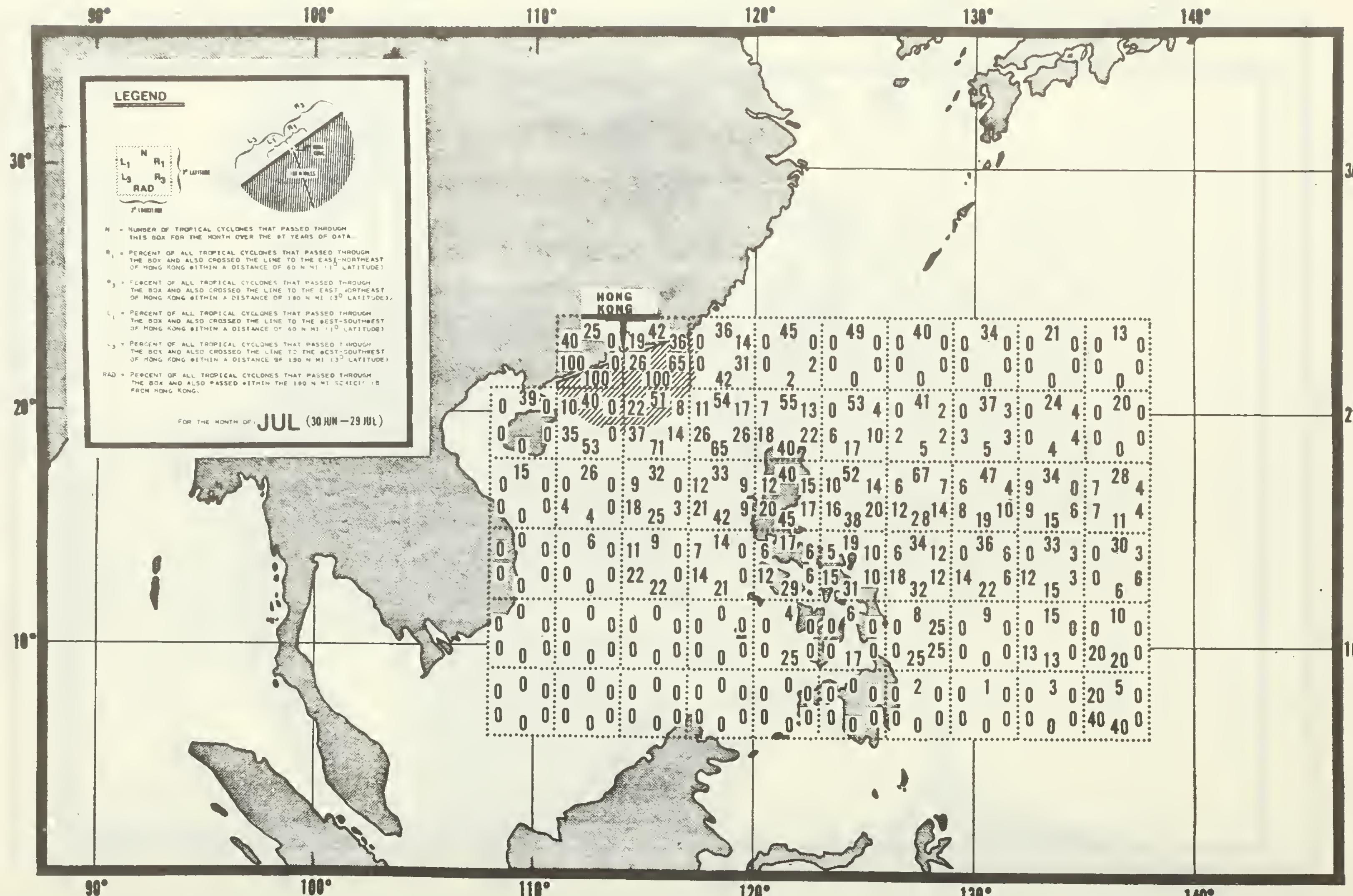

Figure 25. Statistical summary of tropical cyclone tracks that passed within a specified distance from Hong Kong for the month of July. (Based on 87 years of data.)

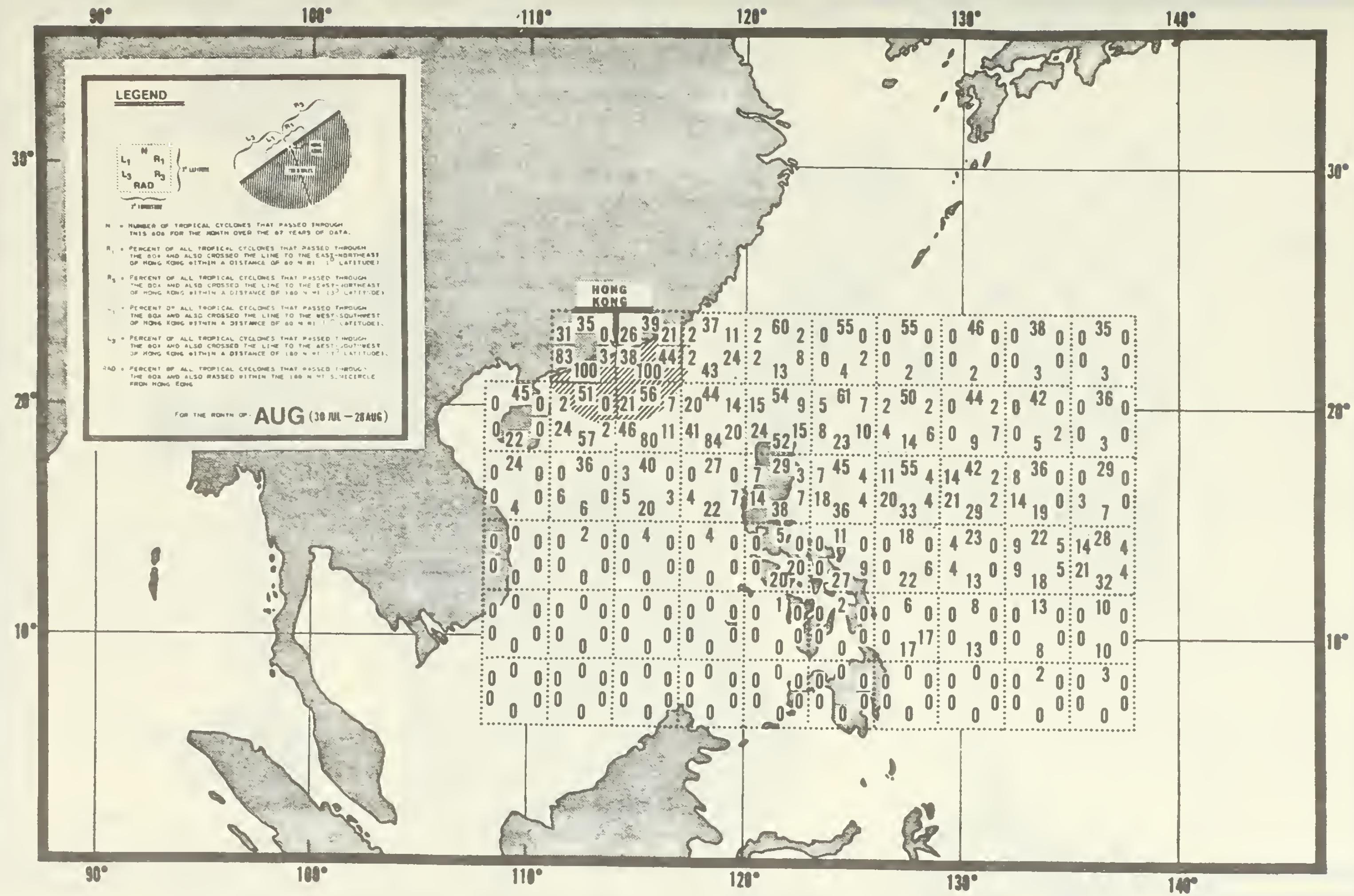

Figure 26. Statistical summary of tropical cyclone tracks that passed within a specified distance from Hong Kong for the month of August. (Based on 87 years of data.)

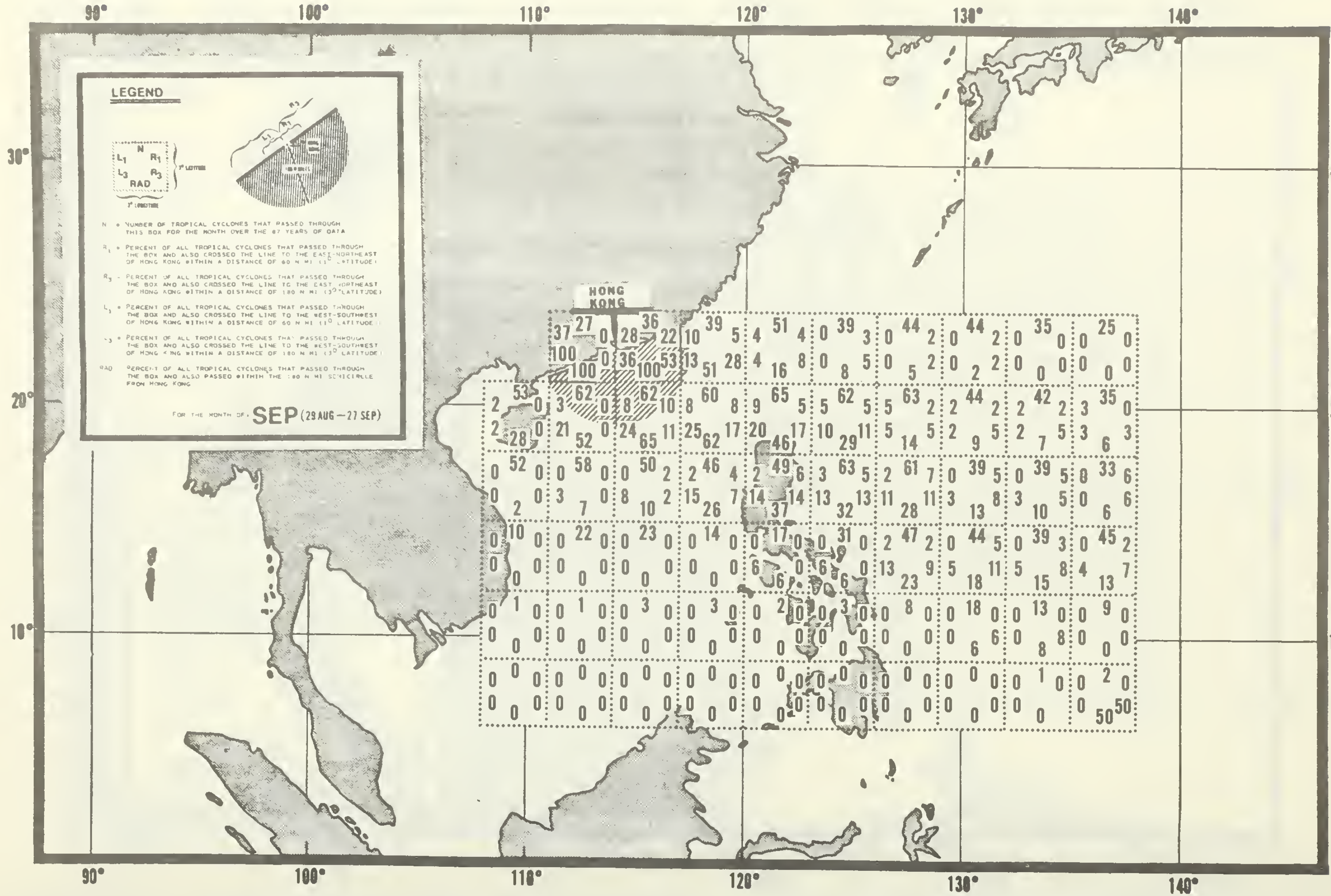

Figure 27. Statistical summary of tropical cyclone tracks that passed within a specified distance from Hong Kong for the month of September. (Based on 87 years of data.)

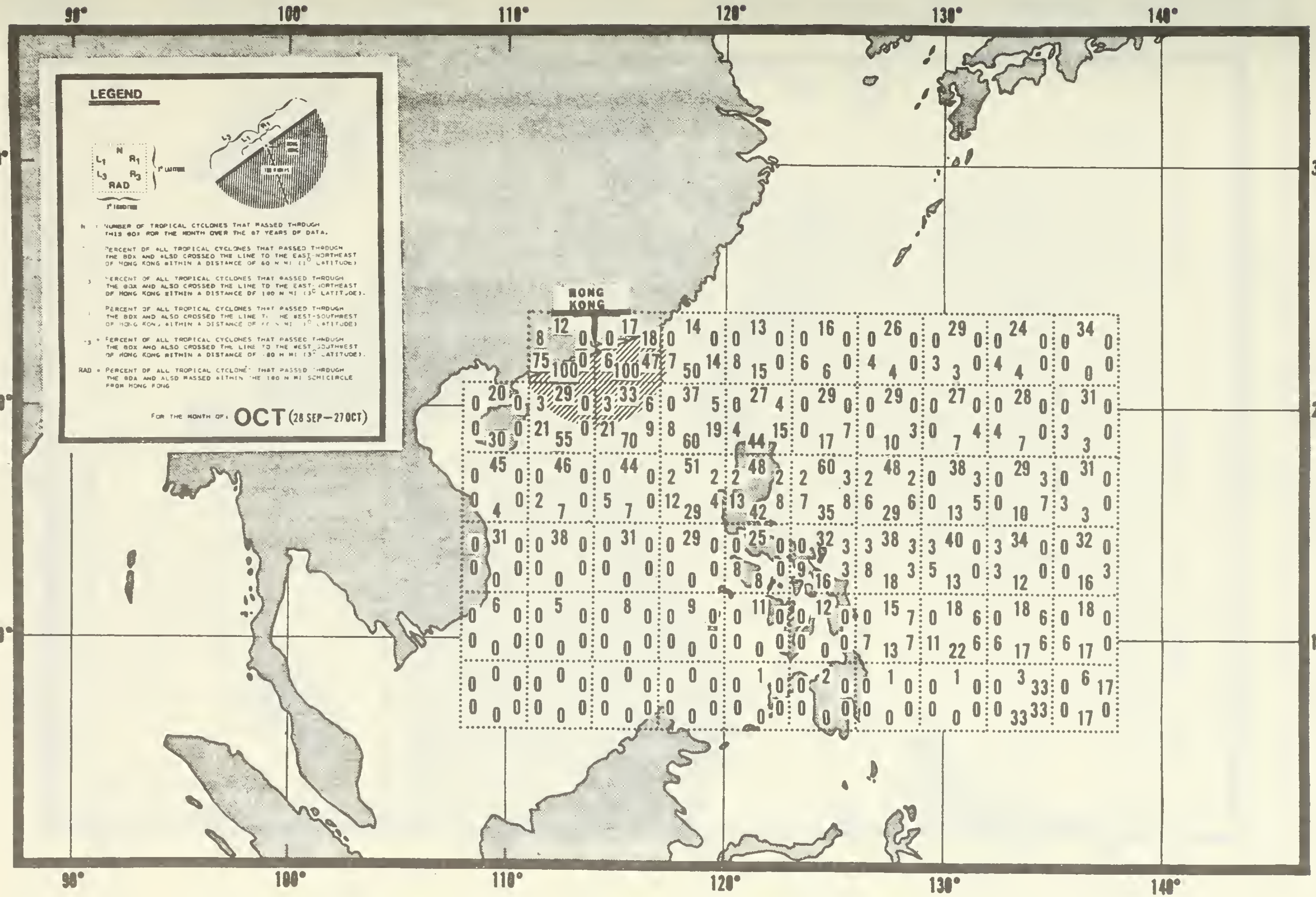

Figure 28. Statistical summary of tropical cyclone tracks that passed within a specified distance from Hong Kong for the month of October. (Based on 87 years of data.)

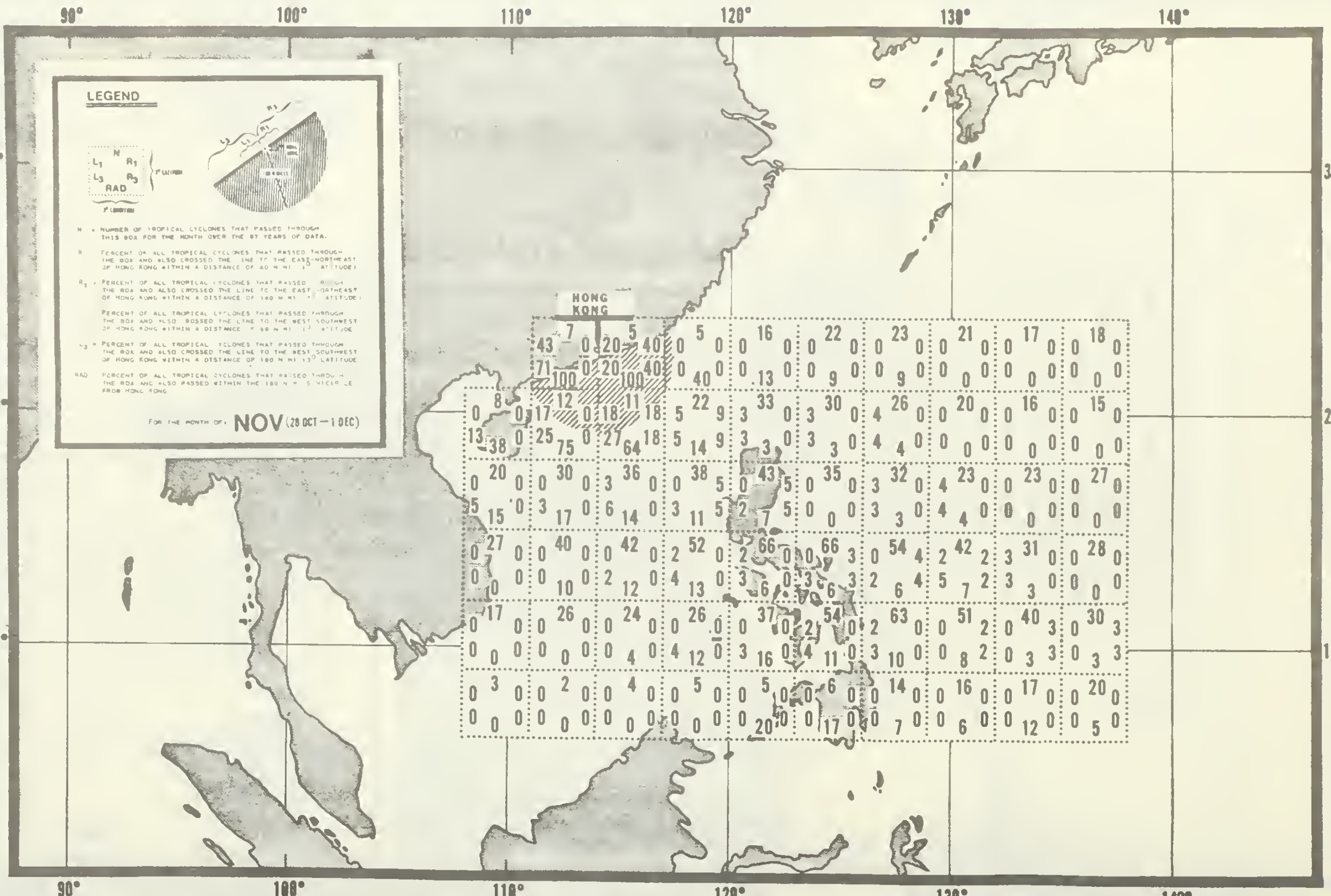

Figure 29. Statistical summary of tropical cyclone tracks that passed within a specified distance from Hong Kong for the month of November. (Based on 87 years of data.)

of that 3°x3° area. To further assess the proximity of the tracks relative to Hong Kong, "R_1", "R_3", "L_1" and "L_3" values were obtained as follows:

R_1: Percentage of all tropical cyclones that passed through the box and and also crossed the line to the east-northeast of Hong Kong within a distance of 60 n mi (1° latitude)

R_3: Percentage of all tropical cyclones that passed through the box and also crossed the line to the east-northeast of Hong Kong within a distance of 180 n mi (3° latitude)

L_1: Percentage of all tropical cyclones that passed through the box and also crossed the line to the west-southwest of Hong Kong within a distance of 60 n mi (1° latitude)

L_3: Percentage of all tropical cyclones that passed through the box and also crossed the line to the west-southwest of Hong Kong within a distance of 180 n mi (3° latitude)[5]

As an example, in Figure 25 for the month of July, the square over the Luzon area of the northernmost Philippine Islands had 40 tracks of tropical cyclones pass through it in the 87 years of data. Of those 40 tracks, 45% passed within the 180 n mi semicircle from Hong Kong. Fifteen percent of the 40 tracks passed within 60 n mi to the east-northeast of Hong Kong (across the line) and 17% passed within 180 n mi to the east-northeast. Similarly, in the same example, 12% of

---

[5]The R_3 value (%) plus the L_3 value (%) will not always equal the percentage of all tropical cyclones to enter the semicircle, 180 n mi since some of the cyclones passed through the area of the semicircle, but failed to cross the line.

the tracks passed within 60 n mi to the west-southwest of Hong Kong (across the line) and 20% passed within 180 n mi to the west-southwest.

For easier evaluation, Figures 30 through 36 have been analyzed with respect to the percentage of tropical cyclones which have passed within the 180 n mi semicircle (the bottom value in each square from Figures 23 through 29). In addition, the approximate time required for the cyclone to cross the east-northeast/west-southwest line through Hong Kong is shown, based on typical speeds of movement of from 8 to 12 kt (the faster the speed, the sooner the time of crossing).

For example, Figure 35 shows, for the month of October, that of all the tropical cyclones over the 87 years of data that crossed over the Northern Luzon area of the Philippine Islands, approximately 50% entered the semicircle 180 n mi from Hong Kong. Additionally, those tropical cyclones which crossed the base of the semicircle (east-northeast/west-southwest line) did so within about 2-1/2 days.

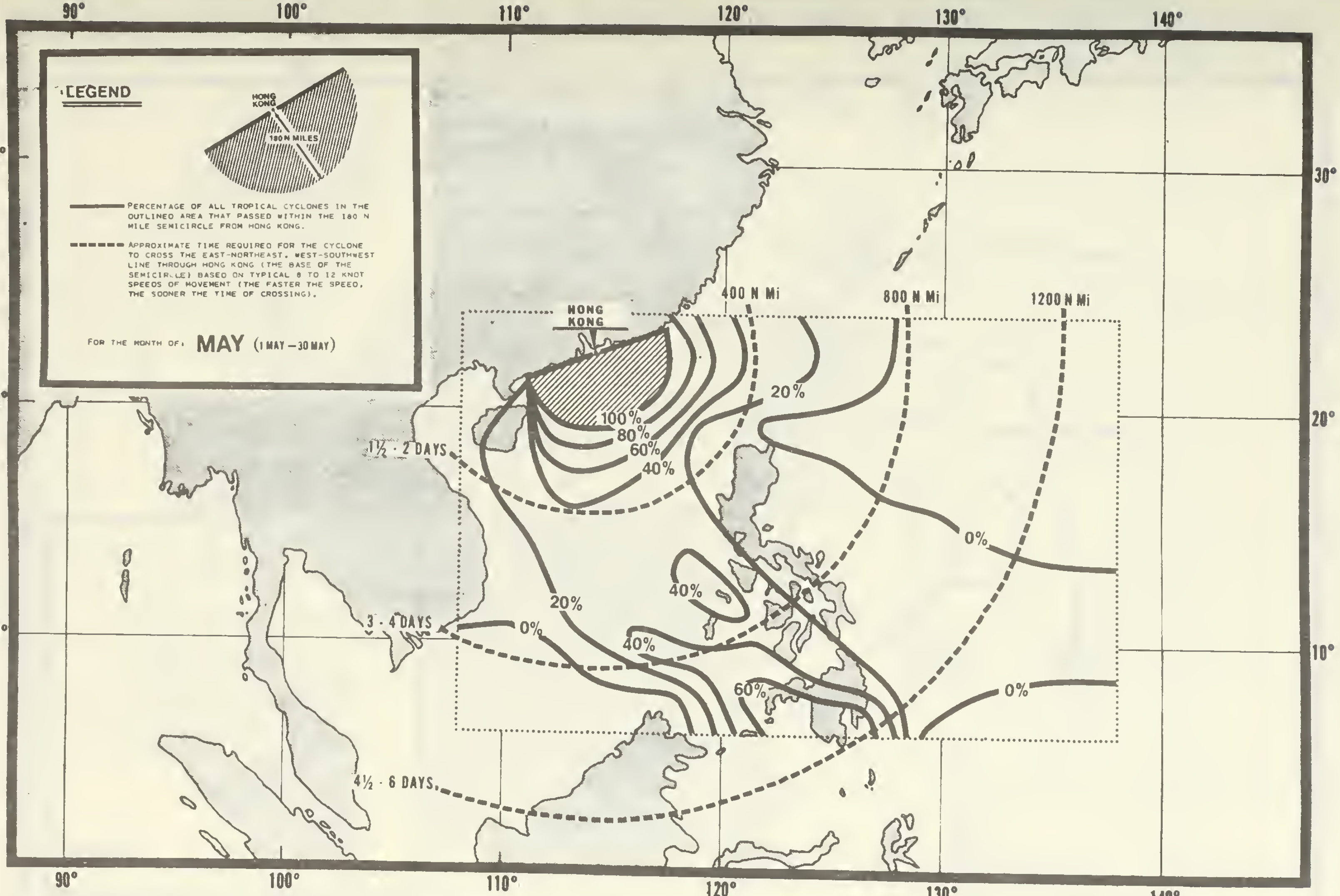

Figure 30. Percentage of tropical cyclones that passed within a semicircle of 180 n mi from Hong Kong for the month of May. (Based on 87 years of data.)

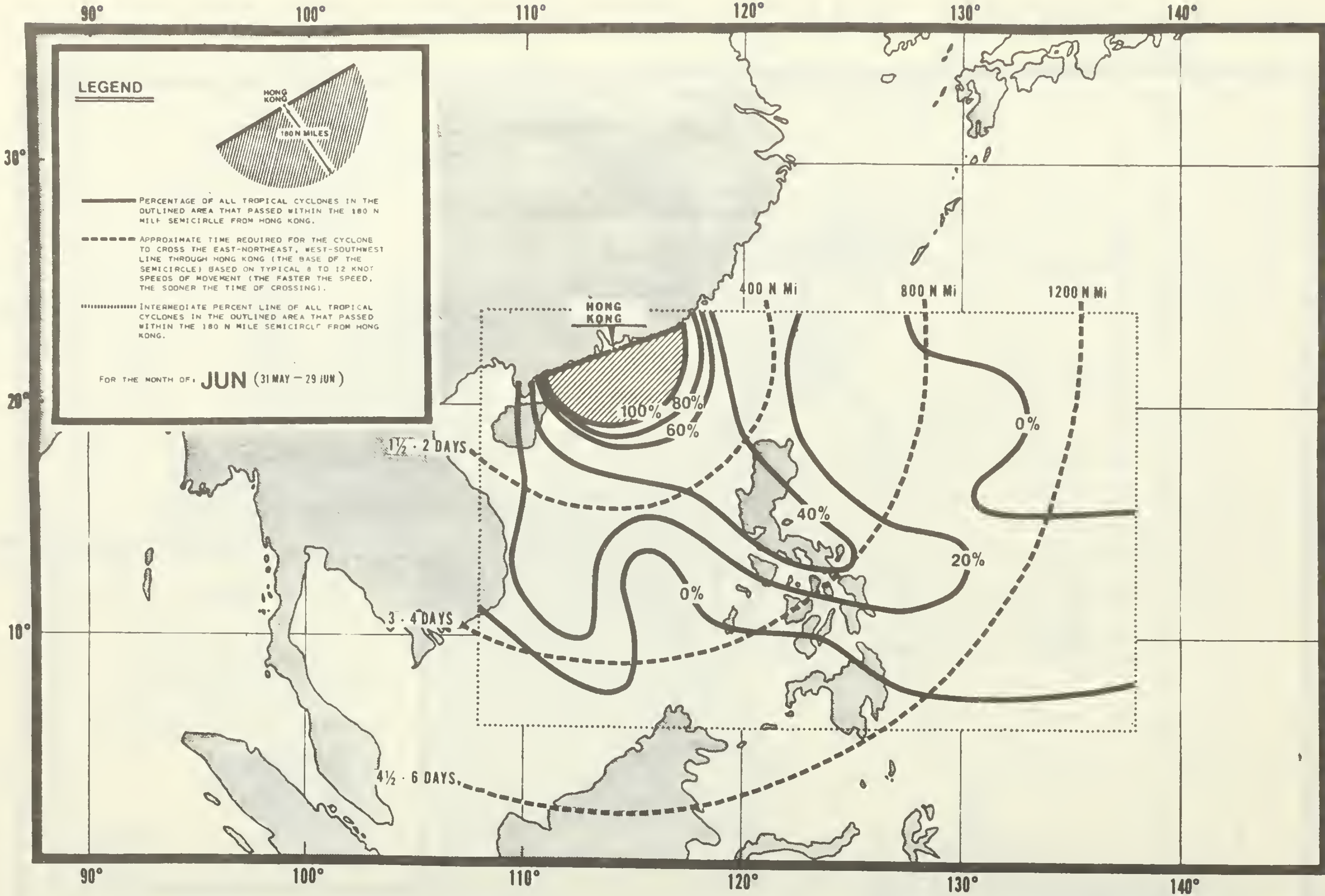

Figure 31. Percentage of tropical cyclones that passed within a semicircle of 180 n mi from Hong Kong for the month of June. (Based on 87 years of data.)

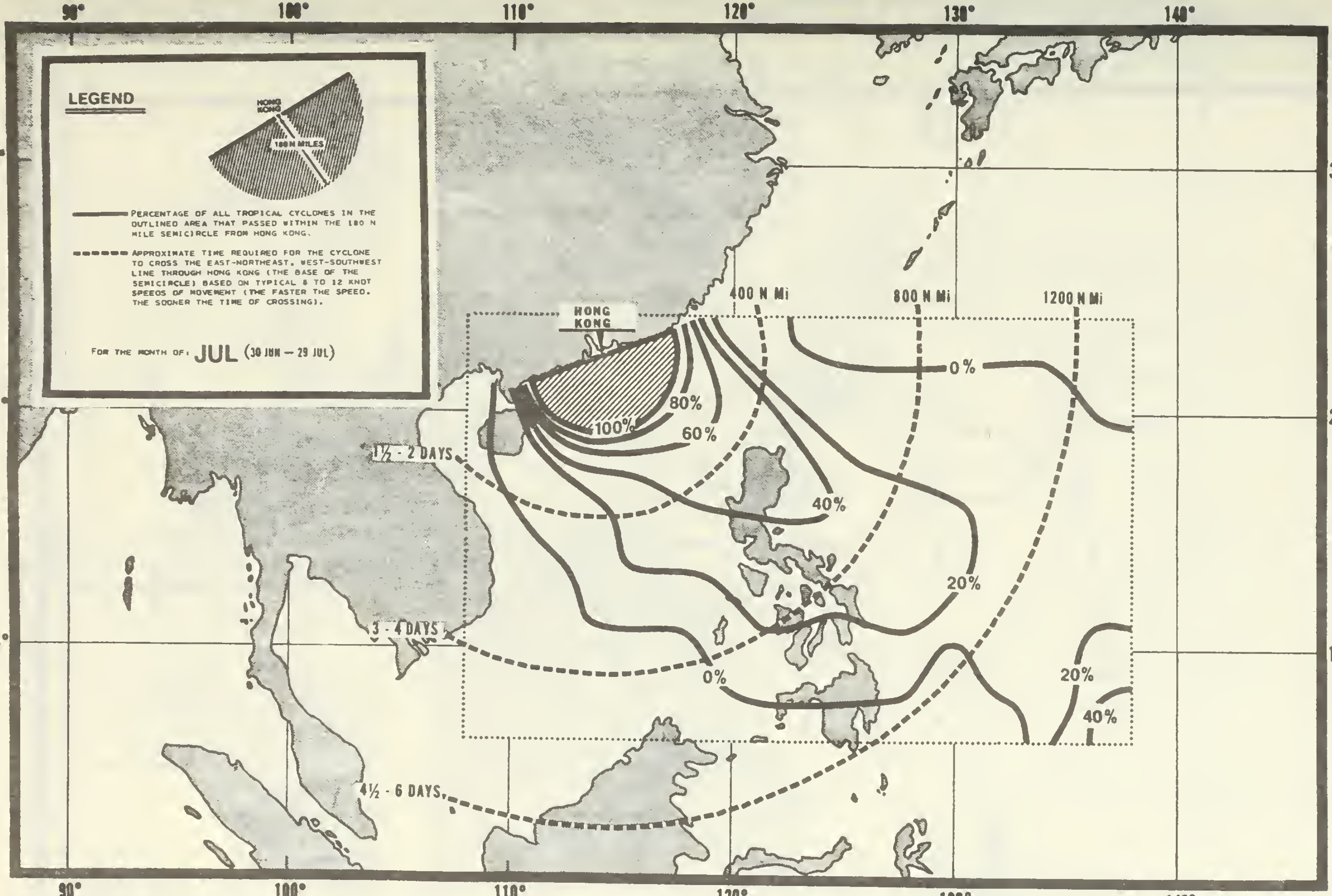

Figure 32. Percentage of tropical cyclones that passed within a semicircle of 180 n mi from Hong Kong for the month of July. (Based on 87 years of data.)

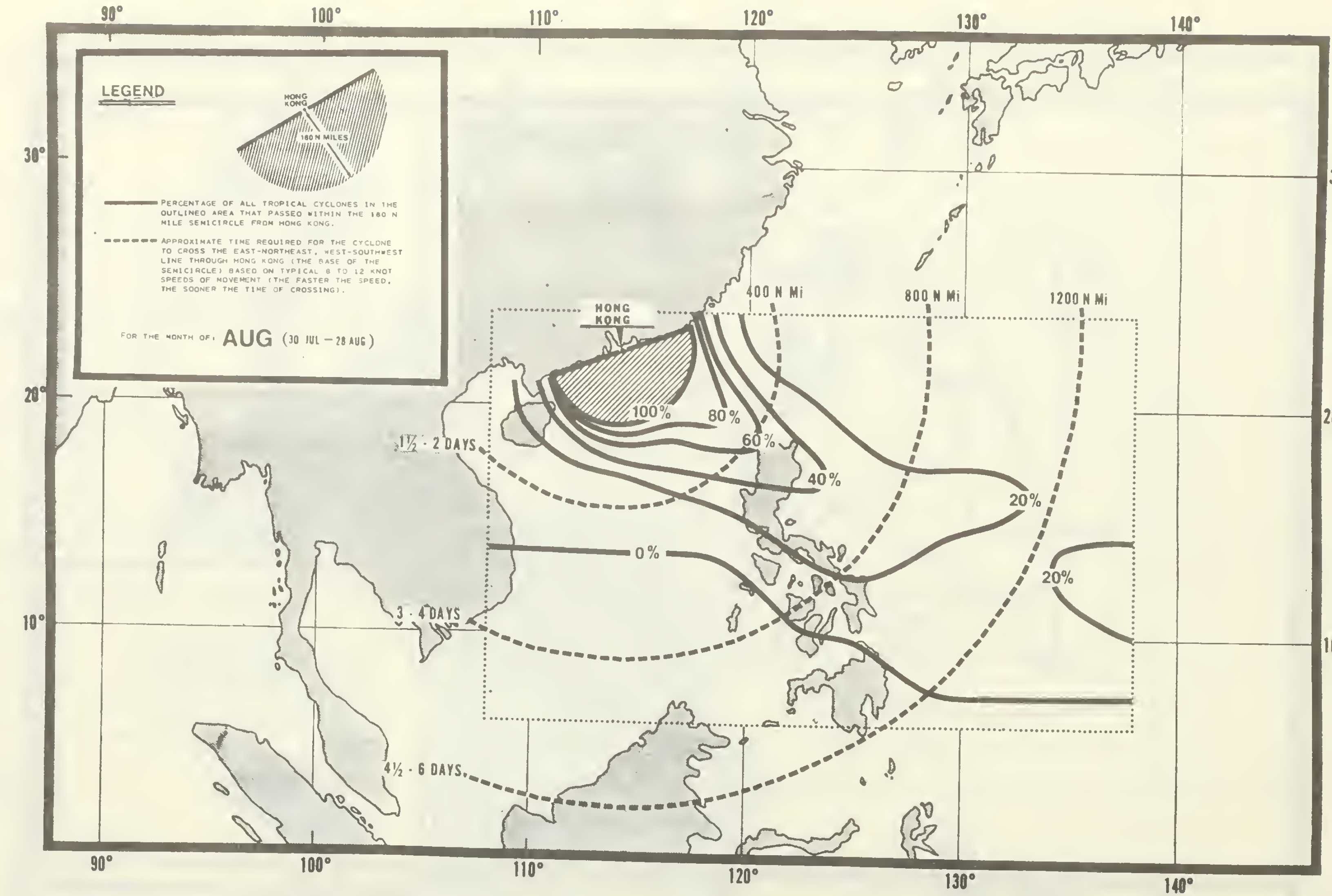

Figure 33. Percentage of tropical cyclones that passed within a semicircle of 180 n mi from Hong Kong for the month of August. (Based on 87 years of data.)

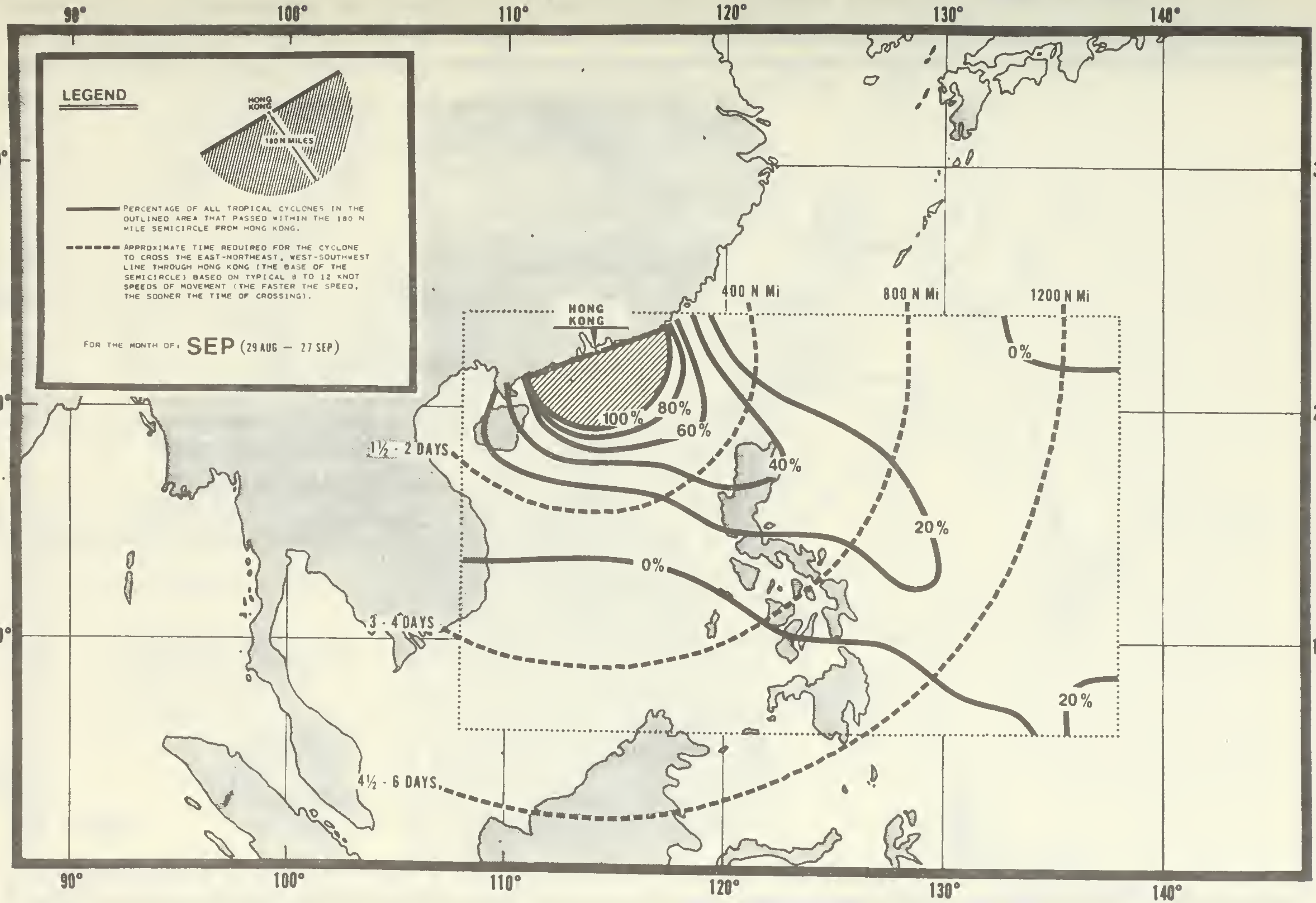

Figure 34. Percentage of tropical cyclones that passed within a semicircle of 180 n mi from Hong Kong for the month of September. (Based on 87 years of data.)

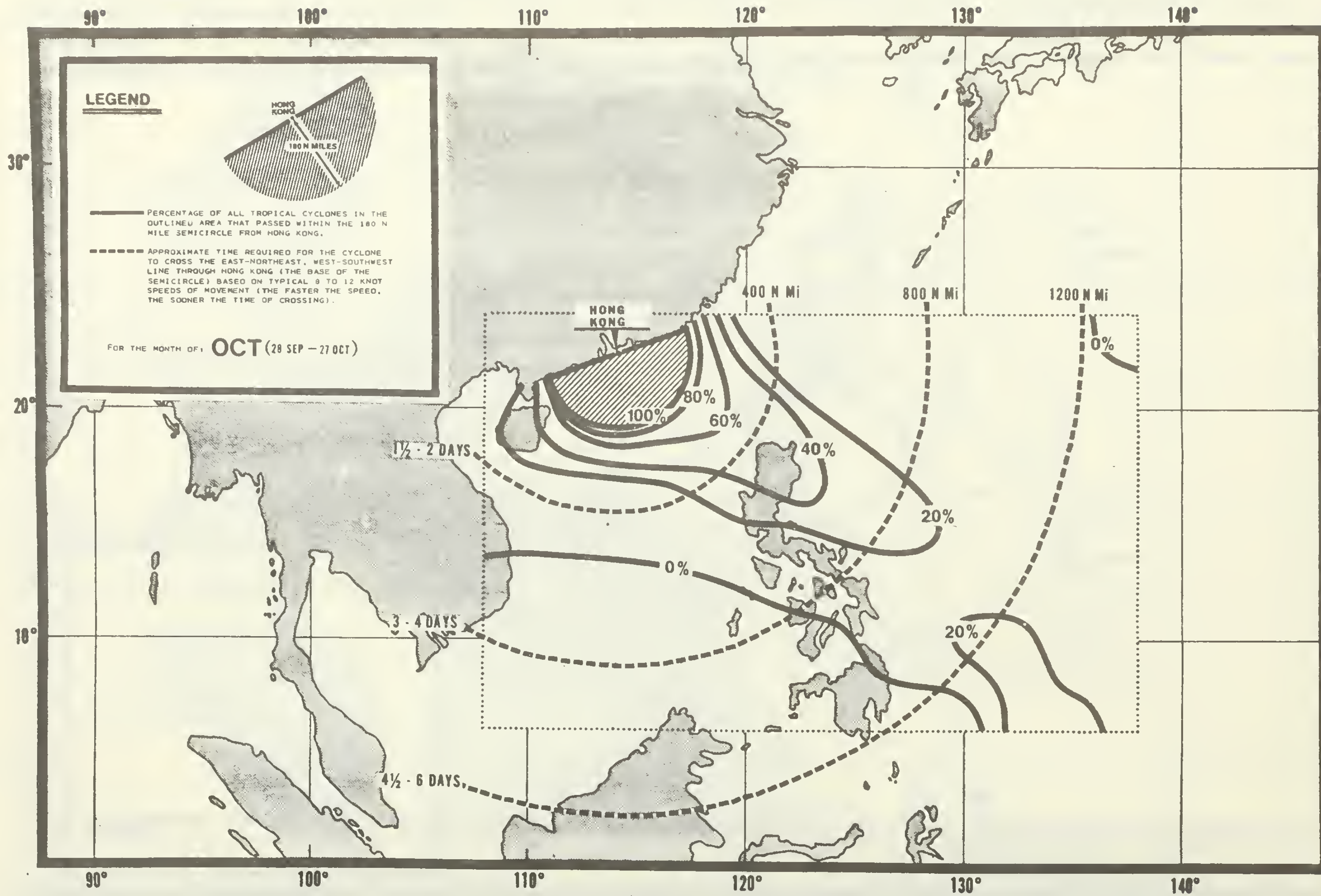

Figure 35. Percentage of tropical cyclone that passed within a semicircle of 180 n mi from Hong Kong for the month of October. (Based on 87 years of data.)

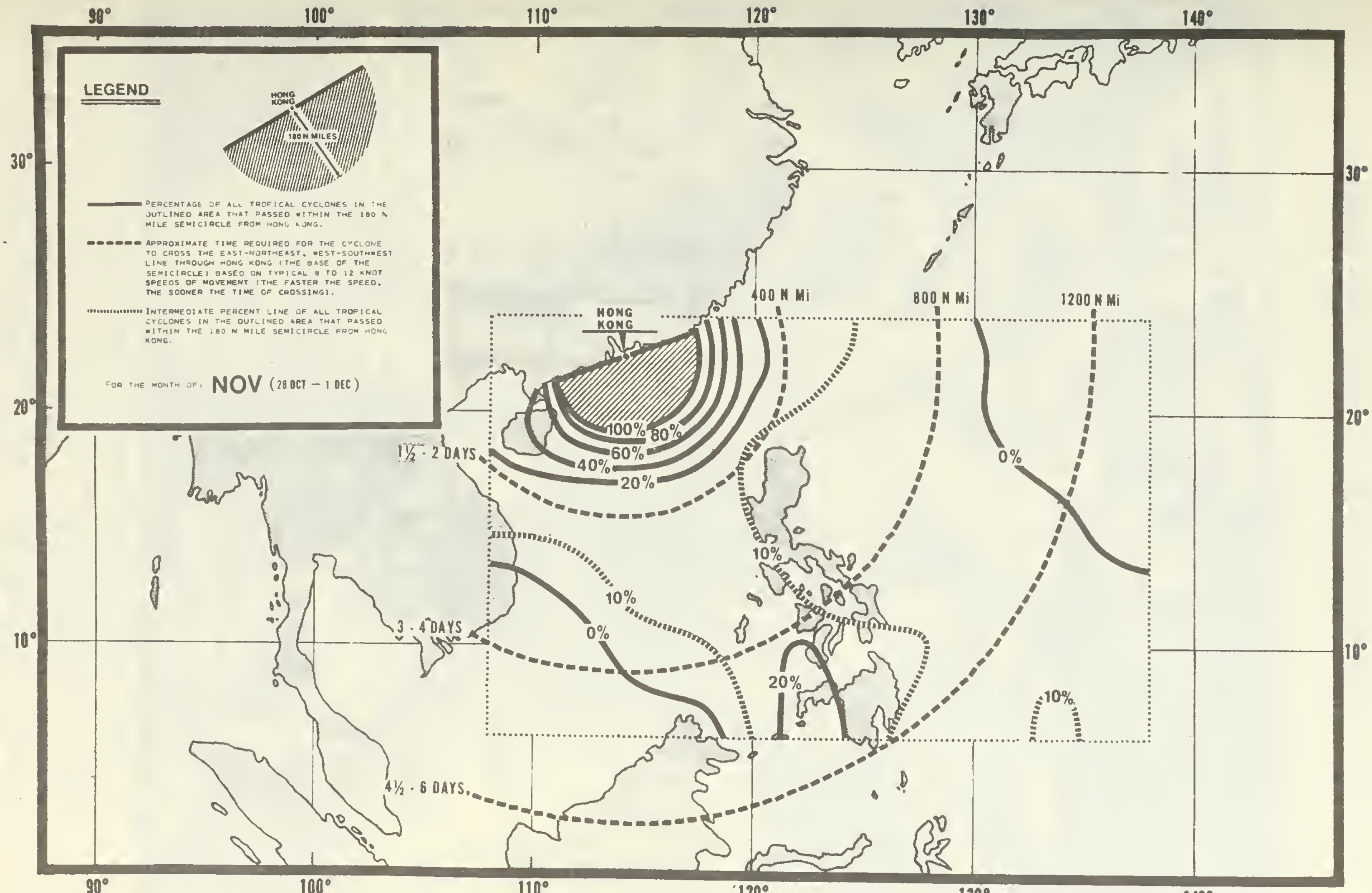

Figure 36. Percentage of tropical cyclones that passed within a semicircle of 180 n mi from Hong Kong for the month of November. (Based on 87 years of data.)

5. CHARACTERISTICS OF HONG KONG HARBOR

5.1 INFLUENCE OF THE TOPOGRAPHY

Figure 37 shows the general east-west orientation of the ranges of hills on both Hong Kong Island and Kowloon. This orientation tends to somewhat channel the winds from approaching tropical cyclones to a general east-west component, even though the circulation of the storm may suggest a more northerly or southerly wind. Figure 37 also shows the three basic harbor anchorage areas: Western Anchorage, Middle Harbor, and Eastern Anchorage and Junk Bay.

General notes on the geography of the south China coast and Hong Kong, and its effect on the wind field of tropical cyclones have been obtained from LCDR A. M. Morrice, Royal Navy, Base Meteorological Officer, Office of the Commodore-in-Charge, Hong Kong. Briefly, Morrice discusses the three anchorage areas (Figure 37) and describes general conditions in each area as a direct result of the passage of a tropical cyclone from various directions relative to Hong Kong (Morrice, 1973a):

1. *General Geography*

   The south China coast lies east-northeast to west-southwest from the Taiwan Strait to the Luichow Peninsula. It forms a rugged and well-indented coastline with a multitude of small islands. In adverse weather conditions it is a dangerous shoreline. Inland, major mountain ranges run approximately east-west.

2. *Hong Kong (refer to Figure 37)*

   The main topographical features of Hong Kong are two ranges of hills. Over the New Territories in the north, a well marked ridge runs from east to west from Kowloon Peak to Tai Mo Shan and Castle Peak. Approximately 8 miles south of this is another ridge, again orientated east-west, consisting of Hong Kong Island itself and Lantau Island, broken by a gap of about 6 n mi.

Figure 37. Topography of Hong Kong and surrounding area. (The grid is the Universal Transverse Mercator Grid with the grid lines every 10 kilometers.) (From Morrice, 1973a.)

To simplify this discussion the harbor will be divided into three sections:

(i) Western Anchorage,
(ii) Middle Harbor,
(iii) Eastern Anchorage and Junk Bay.

The effects of tropical cyclones at various bearings and distances will be discussed. A direct hit or very close pass will also be considered.

a) Tropical cyclone passing to the SE of Hong Kong

The vast majority of tropical cyclones approach Hong Kong from the southeast. The resultant winds are from the north, and because of the rugged terrain to the north, the winds experienced locally are less severe than might otherwise be expected. Any tropical cyclone running inland over 50 n mi east of Hong Kong is likely to have little effect on the harbor. However, as the circulation moves north and weakens, there is often an increase of wind strength from the southwest. This will affect Western Anchorage in particular, which has a long fetch towards the south, and may therefore experience destructive seas.

b) Tropical cyclone passing S to SW of Hong Kong

As the bearing changes from S to SSW the local winds will veer to the east. Because of the east-west orientation of the hills, there is a well marked tendency for the winds to remain easterly in Middle Harbor and Western Anchorage even as the bearing of the tropical cyclone becomes SW or even SSW (provided the center is over about 150 n mi from Hong Kong). In Junk Bay the wind will probably change suddenly to southeasterly and increase with a rapid build-up of wave height under these conditions. In such a situation all sections of the harbor will be exposed and dangerous.

c) *Tropical cyclone moving north passing to the west of Hong Kong*

Provided the landfall is between 50 and 150 n mi west of Hong Kong, winds are unlikely to veer beyond southeasterly, and so Western Anchorage and Middle Harbor will be relatively sheltered, while Eastern Anchorage and Junk Bay would become more exposed. However, once the circulation has hit land winds may become south or southwesterly, as in paragraph (a), with a sudden increase in Western Anchorage.

d) *Direct Hit or Close Pass*

Any tropical cyclone passing within 25 n mi to the east and 50 n mi to the west of Hong Kong will have serious effect on all areas of the harbor. Storm surge can cause dangerous rises in sea level. Sea walls and piers have been known to be awash when the surge coincided with a high tide. Within the harbor the sea becomes very confused with short steep waves. Should the wind go south or southwest, dangerous conditions prevail in Western Anchorage. Obviously, the closer the center passes to Hong Kong, the greater is the effect on the harbor. Unfortunately, there is no particular area of the harbor which could be considered as favorably situated under such conditions.

5.2 STORM SURGE IN THE HARBOR

The natural harbor of Hong Kong, like any other harbor, is subject to "storm surge" effects as the tropical cyclone approaches landfall. Storm surges can be defined as the difference between the observed water level during the storm and that which would have occurred at the same time and place in the absence of the storm (Cheng, 1967). In other words, a storm surge implies a "piling up" of excess water in the harbor due to:

a. the reduction of surface pressure created by the cyclone;

b. wave run-up onto the beaches as a result of winds and seas (dependent upon the shore line characteristics; and

c. accompanying torrential rains and runoff into the harbor (Watts, 1959).[1]

Tropical cyclones which yielded storm surges in Hong Kong harbor greater than two feet for the years 1936-1971 are presented in Table 2. The higher values, near 6 feet, resulted from fast-moving tropical cyclones with accompanying torrential rains and a storm surge maximum that corresponded to the time of the astronomical high tide. Storm surges, coinciding with high tide, can cause a serious rise in the water level resulting in the sea walls and piers becoming awash (Morrice, 1973a).

"Seiche" effects, or the natural period of oscillation between the harbor and incoming swell wave, that can produce a rapid rise and fall of the water level does not appear to be a significant problem in the open-ended harbor of Hong Kong. Additionally, since the harbor is open to both the east and west, it acts to dissipate, to some extent, the seiche and storm surge amplitude (Watts, 1959).

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[1] For a more detailed description of storm surge forecast techniques, the reader is referred to Nickerson, 1971.

Table 2. Storm surges in Hong Kong harbor (from ROHK, unpublished).

YEAR	MONTH	TROPICAL CYCLONE	STORM SURGE IN HONG KONG HARBOR (in feet)
1936	AUG		6.3
1937	SEP		> 6
1962	SEP	WANDA	5.8
1954	AUG	IDA	5.4
1964	SEP	RUBY	4.9
1949	SEP		4.9
1957	SEP	GLORIA	4.4
1964	AUG	IDA	4.3
1954	NOV	PAMELA	3.8
1968	AUG	SHIRLEY	3.6
1960	JUN	MARY	3.6
1965	JUL	FREDA	3.3
1971	JUL	LUCY	3.2
1964	MAY	VIOLA	3.1
1971	JUN	FREDA	2.8
1963	SEP	FAYE	2.8
1971	OCT	ELAINE	2.6
1957	JUL	WENDY	2.5
1967	AUG	KATE	2.4
1964	SEP	BILLIE	2.4
1956	AUG	CHARLOTTE	2.4
1951	AUG		2.4
1969	JUL	VIOLA	2.3
1960	OCT	KIT	2.3
1955	SEP	KATE	2.3
1954	NOV	RUBY	2.2
1958	MAY		2.2
1953	SEP	SUSAN	2.1
1956	OCT	JEAN	2.1
1971	AUG	ROSE	2.1

6. CASE STUDIES

6.1 TYPHOON ROSE (Aug 10-17, 1971)

Figure 38 is the track followed by Typhoon ROSE, giving 6-hour best track positions, speeds of movement, and intensities (U. S. FWC/JTWC, 1971). A brief discussion obtained from the Royal Observatory, Hong Kong follows:

> *In spite of its relatively small size, Typhoon 'Rose' was probably one of the most intense and violent typhoons that have affected Hong Kong. Maximum wind speeds were only slightly lower than in Typhoon 'Ruby' (1964) and Typhoon 'Wanda' (1962) and they occurred during the night whereas both 'Ruby' and 'Wanda' passed in daylight. Like other tropical cyclones that approached from the south, such as Typhoon 'Mary' in 1960, 'Rose' caused very heavy rainfall. The strongest winds were from the east-southeast compared with 'Wanda' when the strongest winds were from the north.*
>
> *On August 10, 'Rose' developed as a tropical depression about 110 n mi west of Guam and soon intensified to a typhoon. It moved west-northwestwards at 11 knots at first but then followed a westerly track at about 14 knots for the next three days. During the period August 11-12, the reported maximum winds within the circulation of 'Rose' fluctuated between storm and hurricane force. However, it remained as a typhoon from August 13 onwards. The center of Typhoon 'Rose' started to cross north Luzon early in the morning of August 14 and entered the South China Sea later in the day.*
>
> *In Hong Kong, the Standby Signal, No. 1, was hoisted at 5 p.m. on August 14, when 'Rose' was centered about 400 n mi southeast of the Colony, and was moving west-northwest at about 10 knots.*
>
> *On August 15, 'Rose' slowed down to about 7 knots as it turned to a northwesterly course. Positions of the typhoon located by reconnaissance aircraft formed a very erratic track and the eye diameter fluctuated between 13 and 50 n mi. However, eight successive reports did show almost continuous intensification with the central pressure falling from an estimated*

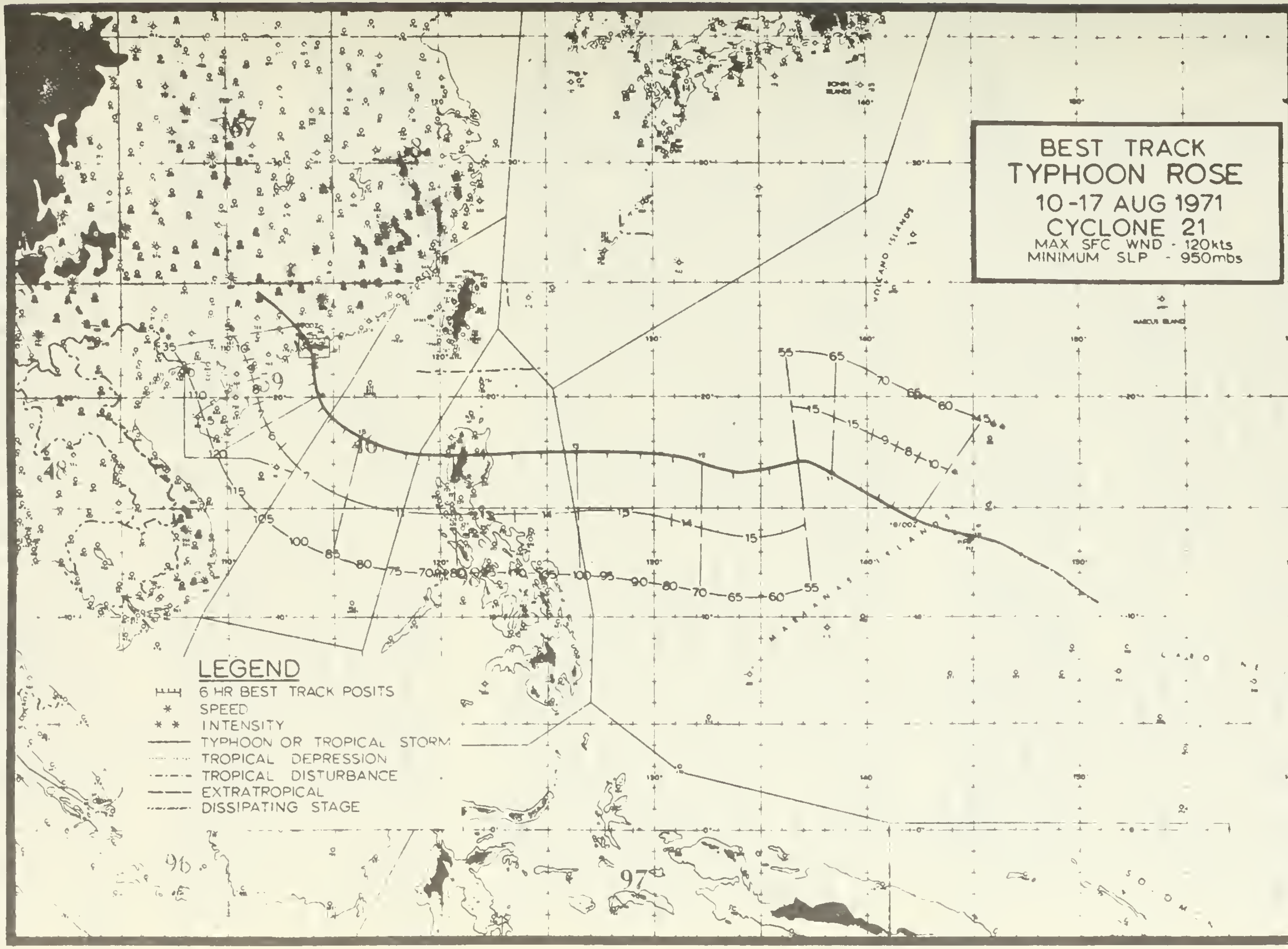

Figure 38. Best track of Typhoon ROSE (Aug 10-17, 1971). (From U. S. FWC/JTWC, 1971.)

988 mb at 1:25 p.m. on August 14 to 957 mb at midnight on August 15-16. At 7 p.m. on August 15, a reconnaissance aircraft reported a maximum surface wind of 130 knots (estimated to be equivalent to a 10-minute mean wind of 115 knots) near the center of 'Rose'. By the late afternoon, it was possible to identify the eye of Typhoon 'Rose' on the Observatory's radar displays. The radar presentation revealed that the rainbands of Typhoon 'Rose' were well organized but only covered an area of about 100 n mi in diameter. The eye was well defined most of the time and was about 20 n mi in diameter. It appeared that 'Rose' was a compact but well developed typhoon.

On August 16, the typhoon began to move on a northerly course at about 7 knots towards Hong Kong and the Strong Wind Signal, No. 3, was hoisted at 5:05 a.m. when it was about 150 n mi away to the south. A statement was issued by the Royal Observatory to warn people that because of the relatively small size of Typhoon "Rose' winds might increase very rapidly over the Colony. The Northeast Gale or Storm Signal, No. 7 (8 NE),[1] was hoisted at 9:50 a.m. as Typhoon 'Rose' continued to approach the Colony. Satellite pictures received at the Royal Observatory during the morning showed that the circulation of 'Rose' was still very well-orgnanized and that clouds covered an area of about 360 n mi in diameter.

At about 10 a.m. a ship, S. S. Nuddea, reported that she was experiencing 90 to 110 knot winds some 10 n mi east-northeast of the typhoon center. Later in the afternoon she sent another report, estimating the central pressure to be 950 mb. At about the same time, another ship within 7 n mi of the center recorded a minimum pressure of 952 mb. At 12:25 p.m. when the eye was about 100 n mi away, the Southeast Gale or Storm Signal, No. 8 (8 SE), was hoisted to replace No. 7 (8NE) to warn a change in the direction of the gales.

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[1]The Signal numbers: 5, 6, 7, and 8 have recently been revised (effective 1 Jan 73) to: 8NW, 8SW, 8NE, and 8SE, respectively. See Figure 45 for Hong Kong storm signals.

During the morning on August 16, surface winds over the Colony were mainly fresh from the northeast quarter. The wind speed increased gradually in the afternoon and gales were experienced in outlying islands by the early evening. Sustained winds of gale force were reported by all local stations soon after dark and the wind direction turned to east and southeast.

The Increasing Gale or Storm Signal, No. 9, was hoisted at 9:10 p.m. on August 16 when 'Rose' was about 50 n mi south-southwest of the Royal Observatory and was replaced by the Hurricane Signal, No. 10, at 10:50 p.m. as the eye of the typhoon continued to move northwards at 10 knots. During the night of August 16-17, winds of hurricane force were experienced in many places, particularly over the western part of the Colony. The edge of the eye of Typhoon 'Rose' passed close to the west of Cheung Chau at about 1:52 a.m. on August 17. The surface wind at Cheung Chau decreased from 66 to below 25 knots in 15 minutes and the sea level pressure fell to 963.2 mb. At about the same time a minimum pressure of 982.8 mb was recorded at the Royal Observatory. The eye crossed Lantau Island, and at Tai O winds fell almost calm around 2:20 a.m. and then returned to hurricane force at 2:47 a.m. The center then passed across Deep Bay and moved away from the Colony north-northwestwards towards Canton.

As the typhoon began to weaken overland, No. 10 was replaced by the Southwest Gale or Storm Signal, No. 6 (8 SW), at 4:40 a.m. This was followed by the Strong Wind Signal, No. 3, at 9:15 a.m. All signals were lowered at noon on August 17.

'Rose' weakened to a tropical storm at about noon on August 17 and dissipated near Canton about 110 miles north-northwest of the Colony. Fresh southerly winds prevailed over the Colony for several hours in the early afternoon.

During the passage of 'Rose', there were 6 hours of gales at the Royal Observatory, while hurricane force winds were recorded for 1 hour at the Hong Kong International Airport, 2 hours at Cape Collinson and Waglan Island, 3 hours at Cheung Chau, and 4 hours at Tate's Cairn. The maximum gusts recorded were 102 knots at Waglan Island, 103 knots

at Cape Collinson, 104 knots at Cheung Chau, 114 knots at the northwest end and 106 knots at the southeast end of Hong Kong International Airport, 120 knots at Tate's Cairn, and 121 knots at the Royal Observatory. At the top of Tai Mo Shan, a maximum gust of 150 knots was recorded at 1:43 a.m. just before the anemometer was broken at 2:11 a.m.

The weather in Hong Kong was cloudy with scattered showers on the morning of August 16, but the showers became frequent and squally during the day and morning of August 17 and a total of 167.5 mm (6.6") of rainfall was recorded at the Royal Observatory in the three hours between 1:00 a.m. and 4:00 a.m. Brilliant flashes of lightning were also observed at this time but because of the noise caused by the wind no thunder could be heard at the observing stations. During the heavy rain on August 17 the trace of the 'Jardi' rate-of-rainfall recorder at Tate's Cairn rose to above the upper limit of the chart and the maximum instantaneous rate which occurred around 8:30 a.m. was estimated to be 513 mm/hour (20.2 in/hour). The weather improved rapidly during the afternoon of August 17 and no rainfall was recorded after 5 p.m.

An unusual phenomenon observed was the development of sea fog at Waglan Island, Cheung Chau and Cape Collinson during the morning of August 18. This was probably caused by a lowering of the sea surface temperature by Typhoon 'Rose'. Fog is rare in Hong Kong in August.

The following daily amounts of rainfalls were recorded at the Royal Observatory:

August 14	Trace
August 15	Nil
August 16	52.8 mm (2.1 in)
August 17	288.1 mm (11.3 in)

The daily total rainfall of 288.1 mm (11.3 in) on August 17 is the highest value ever recorded in one calendar day in August in Hong Kong.

The times and heights of the highest tides and maximum storm surges recorded at the various locations in the Colony during Typhoon 'Rose' were as follows:

Location	Highest Tide Above Chart Datum			Maximum Storm Surge Above Predicted Level		
	Height	Date	Time	Height	Date	Time
North Point (see Fig. 3)	2.56 m (8.40 ft)	Aug. 17	2:20 a.m.	0.64 m (2.10 ft)	Aug. 17	2:20 a.m.
Tai Po Kau (see Fig. 2)	3.00 m (9.84 ft)	Aug. 17	3:25 a.m.	0.98 m (3.22 ft)	Aug. 17	3:25 a.m.
Chi Ma Wan (Lantau) (see Fig. 2)	2.98 m (9.7 ft)	Aug. 17	1:05 a.m.	1.23 m (4.04 ft)	Aug. 17	1:05 a.m.

Wind-generated waves of about 9.5 metres (31.2 ft) were registered by the electronic wave-recorder near Waglan Island at noon on August 16 just before the submerged cable lead was broken. However, waves estimated to be 14 metres (46 ft) high were observed by H.M.S. Argonaut about 70 n mi north of the typhoon during the afternoon on the same day.

Tragically, 'Rose' was the worst typhoon for fatalities and heavy damage on property in Hong Kong since Typhoon 'Wanda' in 1962 . In general, heavier damage was reported in the western than in the eastern side of the Colony. According to preliminary reports, 74 people were killed and a further 50 are missing and presumed dead. A total of 5,644 people from 1,032 families was made homeless and 653 huts were destroyed. 286 persons were injured of whom 90 had to be hospitalized. 26 ocean-going vessels went aground and 2 were sunk. 300 small craft, including 100 pleasure craft were sunk or damaged. Six of the 14 hydrofoils on the Hong Kong-Macau run were put out of action and a total of 6 Hong Kong & Yaumati ferries went aground while taking shelter in Kowloon Bay.

The USS REGULUS (AF-57) was one of the 26 ocean-going vessels that ran aground as a direct result of the passage of Typhoon ROSE. Photographs of the damage sustained by the REGULUS when she ran aground on Kau Yi Chau Island (see Figure 2) after dragging anchor for over a mile in the vicinity of the Western Anchorage area, appear in Figures 39 and 40. The REGULUS steamed to the anchor at 1 to 8.8 kt which was not sufficient to hold its position in the 65 kt sustained winds with gusts in excess of 100 kt. This tragedy represented an $8-$10 million dollar loss to the U. S. Navy and serves to stress the importance of never underestimating the destructive capability of a typhoon.

The REGULUS was not the only ship tragedy during the passage of ROSE, as illustrated by the list of vessel casualties (structural damage, aground, or sunk) in Table 3 and the graphic display of ships aground in Figure 41.

6.2 TYPHOON WANDA (Aug 27-Sept 2, 1962)

Figure 42 is the track followed by Typhoon WANDA, giving 6-hour best track positions, speeds of movement, and intensities (U. S. FWC/JTWC Guam, 1962). A brief summary of Typhoon WANDA is now presented as was given by the Royal Observatory, Hong Kong (Peterson and Cheng, 1966):

> *"WANDA" formed on August 27 as a tropical depression over the Pacific about 1300 n mi to the east-southeast of Hong Kong. Moving west-northwest towards the Luzon Strait at fifteen knots it gradually intensified and by the next day was a severe tropical storm. On August 29 a U.S.A.F. reconnaissance aircraft flew into the eye of the storm and reported that the wind strength had reached hurricane force. By this time the circulation of the typhoon covered a wide area about 1000 n mi across.*

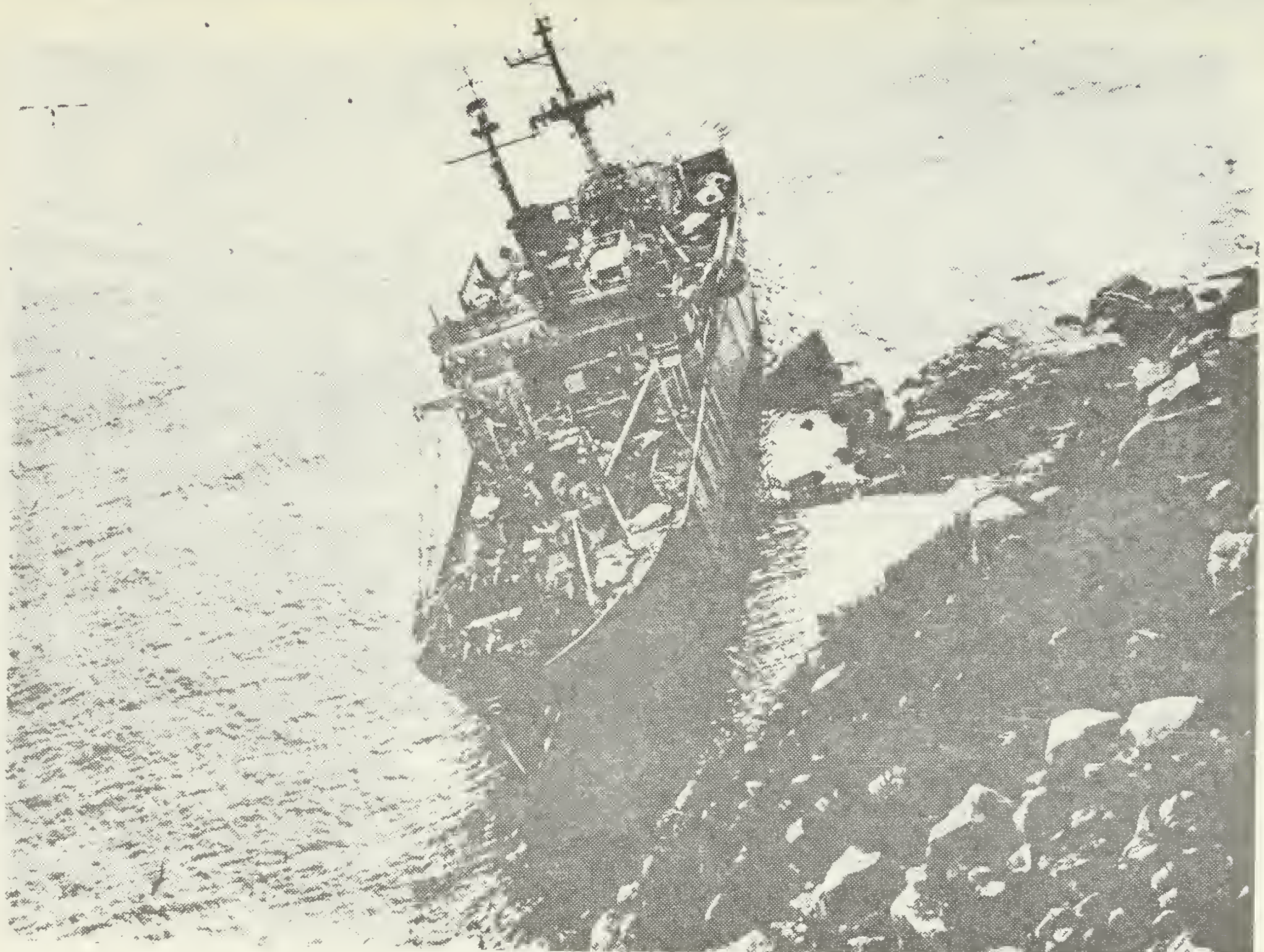

Figure 39. USS REGULUS (AF-57) aground on Kau Yi Chau Island, Hong Kong, as a result of the passage of Typhoon ROSE. (From U. S. Office of the Judge Advocate General, 1971.)

Figure 40. USS REGULUS (AF-57) aground on Kau Yi Chau Island, Hong Kong, showing structural damage as a result of the passage of Typhoon ROSE. (From U. S. Office of the Judge Advocate General, 1971.)

Table 3. Listing of vessel casualties incurred at Hong Kong during Typhoon ROSE, (from, FWC/JTWC, 1971).*

VESSEL	FLAG	TONNAGE
GREEN BAY	United States	11,021
FLYING DRAGON	United States	8,243
REGULUS	United States	---
AMERICAN HAWK	United States	7,909
FATSHAN (Ferry)	British Commonwealth	2,637
RED SEA	British Commonwealth	7,026
DWARKA	British Commonwealth	4,851
HUNTSLAND	British Commonwealth	9,353
EASTERN CAPE	British Commonwealth	6,205
JADE LILY	British Commonwealth	11,753
SEA CORAL	British Commonwealth	10,421
LEE HONG (Ferry)	British Commonwealth	1,127
MACAU (Ferry)	British Commonwealth	3,670
KIM SENG	British Commonwealth	---
GALLANTRY	Panama	7,582
MONRUBY	Panama	5,312
WINFIELD TRADER	Panama	11,038
KAOHSIUNG	Panama	1,289
TIEN HONG	Liberia	12,417
BILLY	Liberia	8,705
SHONAN MARU	Japanese	2,116
KYOHO MARU	Japanese	2,998
LAOSHAN	Somali	10,087
TAIPIENG	Somali	5,676
NURITH	Israel	6,982
COMANDANTE CAMILO CIENFUEGOS	Cuba	9,735
WORLD DALE	Greece	15,729
KOTA SENTOSA	Singapore	---
JILIN	China	6,804
FERNBANK	Norway	8,981
GUIMARAS	Philippines	3,555
WATUDAMBO	Indonesia	2,165
TUNG THAI	Taiwan	2,492
WAH FAT	Taiwan	---
ARISA	Taiwan	---

*SOURCE 1. Casualty Returns, The Liverpool Underwriters' Association - Aug 1971.
2. Mariner's Weather Log, NOAA - Vol 16, No. 1

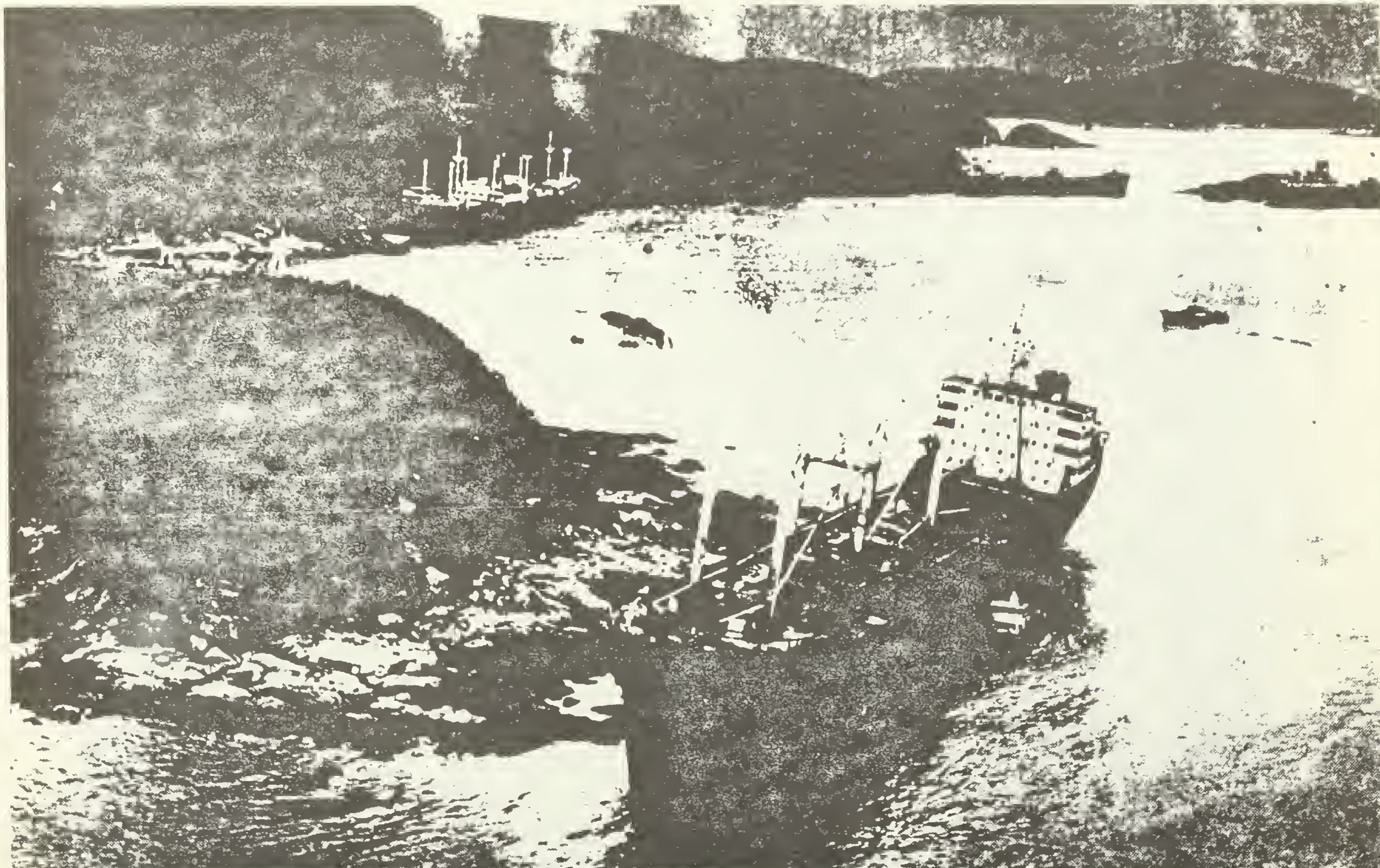

Figure 41. Victims of Typhoon ROSE. Freighters run aground on Lantau Island, Hong Kong surround the capsized Macao-Hong Kong Ferry, FATSHAN. (Vessels seen include the FERNBANK, WINDFIELD TRADER, GALLANTRY, KOYOHO MARU, and KAOSHSIUNG -- Courtesy of the South China Morning Post.) (From U. S. FWC/JTWC, 1971.)

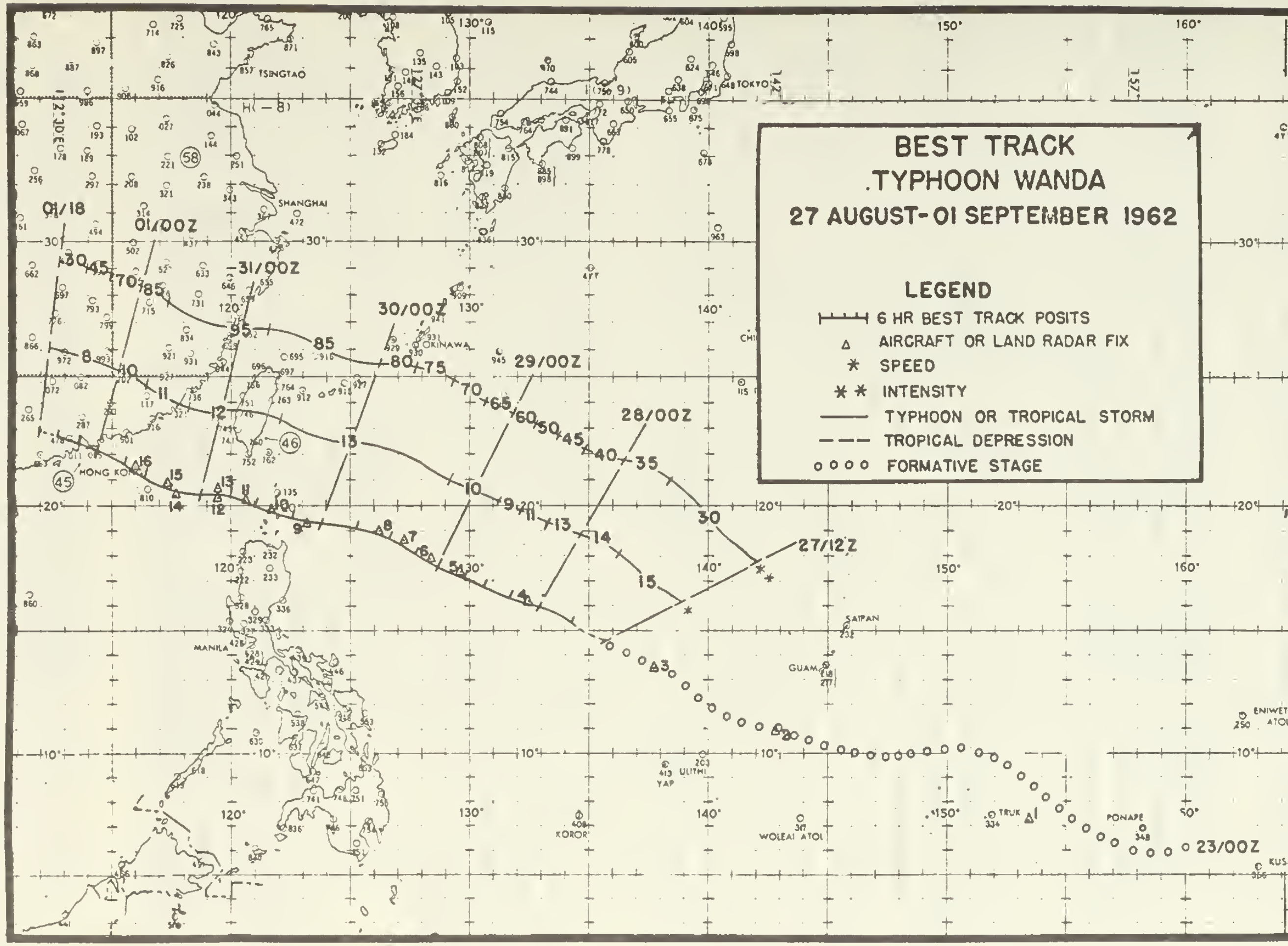

Figure 42. Best track of Typhoon WANDA (27 August-1 September, 1962). (From U. S. FWC/JTWC, 1962.)

Another aircraft reconnaissance on August 30 indicated that further intensification had occurred and 80 knot winds were reported near the center. It continued to move towards Hong Kong and by the evening it was centered 400 n mi east-southeast of the Colony, over the southern part of the Luzon Strait. No. 1 Local Storm Signal was hoisted at 7:45 p.m.

Up to this time the winds over the Colony had been generally light or moderate but early the next morning they set in from the north and showed signs of freshening. The No. 3 Local Storm Signal was hoisted at 4:10 p.m. on August 31.

The first rain came with a squall of north-northwest winds which moved west across the Colony during the early evening. By 9 p.m. typhoon "WANDA" was centered about 155 n mi east-southeast of the Colony and was moving west or west-northwest at 10 knots. Although no strong winds had yet been reported it became certain that "WANDA" would pass close to the Colony the next day and No. 7 (8 NE) signal was hoisted at 10:50 p.m. The wind speed reached gale force with gusts to 48 knots at Waglan Island at 2:00 a.m. on September 1 when "WANDA" was centered about 105 n mi away.

At 4:15 a. m. No. 9 Local Storm Signal was hoisted to indicate that the gales were expected to increase. By this time winds over the harbor were averaging about 30 knots from the north-northwest but Waglan Island was reporting 40 knots with gusts to 57 knots.

No. 10 Local Storm Signal was hoisted at 6:15 a.m. on September 1 when "WANDA" was centered some 50 n mi away and moving directly towards the Colony. As the approach coincided with high tide, a warning was issued at 6:30 a.m. stating that the water would rise 6 feet above normal high tide in the harbor and much higher in Tolo Harbor with flooding over low-lying land.

By 9 a.m. Typhoon "WANDA" was centered over the eastern waters of the Colony and hurricane force winds were blowing over most of Hong Kong. Gusts of 116 knots were reported from Waglan Island and 154 knots from Tate's Cairn. The anemogram from the Royal Observatory showed that the 10 minute mean wind reached typhoon force at about

9:20 a.m. and rose to a maximum of about 78 knots at about 9:30 a.m. It decreased slightly as the eye passed and then increased again to about 74 knots at 10:00 a.m. At about 9:30 a.m. a maximum gust of 140 knots was recorded at the Royal Observatory as the typhoon center was passing south of Waglan Island. After making corrections for the reduced density of the air and the calibration of the anemometer the maximum gust at the Royal Observatory was 145 knots (167 m.p.h.) and at Tate's Cairn 164 knots (189 m.p.h.). The center of Typhoon "WANDA" passed about 10 n mi south of the Royal Observatory at 9:50 a.m. still moving west-northwest at 11 knots. Tides in Tolo Harbor rose about 10 feet above the normal high tide or 17 feet above chart datum, while the crests of wind-driven waves at Tai Po Kau reached about 23 feet above chart datum. Altogether nearly 12 inches of rainfall were recorded at the Royal Observatory. At 11:30 a.m. the eye of "WANDA" passed very close to Cheung Chau and it was almost calm there for a while. With the typhoon passing close to the south there was a rapid veering of winds to southeast over the whole Colony and although there was a temporary lull in many places the wind strength increased again. At noon gusts of 82 knots were still being reported from Waglan Island and 80 knot gusts were registered at the Royal Observatory at 12:30 p.m. By this time the typhoon was centered close to Lantau and was moving away to the west at 12 knots. No. 10 signal was replaced by No. 6 (8 SW) at 2:15 p.m. to indicate that the wind might veer to the southwest. Although gales were still blowing at Waglan Island and Cheung Chau up to 6 p.m. the wind over the harbor area had dropped below gale force by this time.

No. 3 signal replaced No. 6 (8 SW) Local Storm Signal at 7:05 p.m. and, as strong winds persisted, it could not be lowered until 12:45 a.m. on September 2 when all danger had passed. The typhoon moved inland over Kwangtung and weakened rapidly during the morning.

A summary of wind observations taken while Typhoon WANDA moved inland near the local area is shown in Table 4, recorded both at the Royal Observatory (ROHK) and on Waglan Island outside the approach to the harbor. Note, in general, the

Table 4. Summary of observations during Typhoon WANDA, 1962 (Peterson and Cheng, 1966)

Sept. 1 1962 H.K. ST. Time	Royal Observatory					Waglan		
	M.S.L. Pressure Millibars	Hourly Mean Wind Direction	Kt	Max. Gust Kt	Rainfall in Preceding Hour mm	Hourly Mean Wind Direction	Kt	Max. Gust Kt
Midnight	993.2	340	17	42	1.3	330	29	48
1	991.7	330	20	42	Trace	330	36	49
2	988.8	330	21	46	Trace	330	40	54
3	985.8	340	29	61	1.4	330	44	68
4	983.0	330	31	60	0.5	330	45	65
5	980.5	340	29	58	2.8	340	50	76
6	977.7	320	36	71	4.1	330	59	78
7	970.7	320	45	86	14.8	330	73	111
8	963.2	360	54	113	55.1	320	63	117
9	958.2	010	68	140	27.8	080	27	47
10	955.1	050	48	96	3.2	150	51	72
11	964.0	130	40	81	2.6	160	61	82
12	974.3	160	36	80	1.3	160	54	78
13	980.8	180	33	77	2.6	160	49	63
14	984.3	170	35	78	4.7	160	45	63
15	986.2	170	30	71	1.6	160	44	60
16	988.0	180	23	55	2.8	160	39	53
17	989.6	180	23	45	5.6	150	35	48
18	990.9	180	19	43	1.9	150	31	44
19	992.1	180	20	49	9.9	140	31	45
20	992.8	180	16	39	18.0	130	28	42
21	994.3	170	16	38	18.3	130	30	42
22	995.1	170	16	35	7.2	130	30	40
23	995.9	180	15	39	7.0	130	27	38

relatively lower mean wind speeds throughout the period at the Royal Observatory compared to Waglan Island as a result of the protection afforded by the ranges of hills referred to under topography (paragraph 5.1).

Damage and casualties were widespread throughout the Colony with the passage of Typhoon WANDA. One hundred and thirty people were killed and 53 were reported missing. Approximately 72,000 people were registered as being homeless. Of a total of 20,287 small craft in Colony waters, 726 were wrecked, 571 were sunk and 756 damaged. Of a total of 132 ocean-going ships, 24 were beached and 12 were involved in collisions. Figure 43 shows the SS CRONULLA (2,330 tons) capsized after striking the sea wall and jetty at North Point (Figure 3) (Peterson and Cheng, 1966).

6.3 COMPARISON OF TYPHOON ROSE AND TYPHOON WANDA

Although both storms caused severe damage to the Hong Kong area and shipping in the harbor, they had differing characteristics. Typhoon ROSE approached Hong Kong from the south at a relatively slow 7-8 kt, whereas Typhoon WANDA came from the southeast with a prior movement of 12-13 kt. The maximum storm surge recorded in Hong Kong harbor for Typhoon ROSE was 2.1 ft compared to 5.8 ft with Typhoon WANDA (see Table 2). Approaching Hong Kong, Typhoon ROSE possessed winds of greater intensity at its center (near 115 knots sustained) while Typhoon WANDA maintained a lesser 90 kt sustained wind (see Figures 38 and 42). The size of circulation of Typhoon ROSE, was small compared to Typhoon WANDA which had an extremely large circulation pattern. Both storms did, however, pass within 10 n mi of the Colony creating a path of destruction as they moved across the China coast and then rapidly dissipated over land.

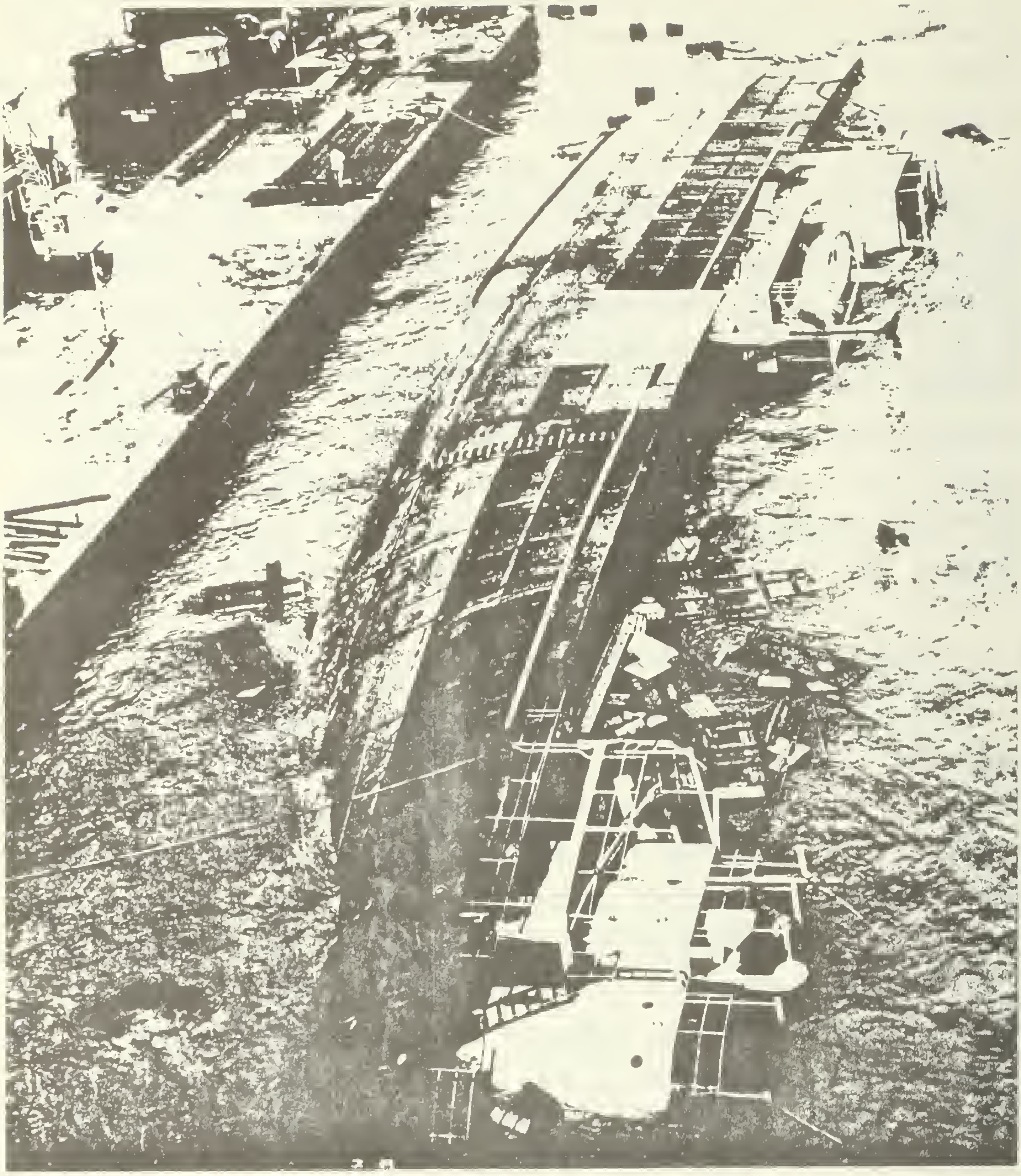

Figure 43. S. S. CRONULLA, 2,330 tons, capsized after striking the sea wall and jetty at North Point with the passage of Typhoon WANDA. (From Peterson and Cheng, 1966.)

7. PREPARATION FOR HEAVY WEATHER

7.1 TROPICAL CYCLONE WARNINGS

Through aircraft reconnaissance and satellite observations modern techniques for locating tropical cyclones and monitoring their progress have become quite sophisticated compared to early mariner days. Nevertheless, the present state of meteorological knowledge does not permit a perfect prediction of storm movements. As stated previously, many variables exist which can alter the path of a typhoon, hence, every typhoon should be treated with the utmost respect.

COMSEVENTHFLT OPORD 201-(YR), Annex W, describes the techniques to be used when plotting the Fleet Weather Central/ Joint Typhoon Warning Center (FWC/JTWC) typhoon warning track positions. The average 24-hour forecast error of 135 n mi should always be incorporated when plotting the 24-hr forecast position in order to expand the radius of 30 kt winds, given in the warning, by the average forecast error. Figure 44 demonstrates this procedure and utilizes the 135 n mi average 24-hr forecast position error in obtaining the "danger area." With the advent of new techniques, better computer systems, and experienced personnel, this average error is gradually being reduced by FWC/JTWC, Guam to near 100 n mi. However, the 135 n mi error should still be used in compliance with COMSEVENTHFLT OPORDS. Similarly, the 48-and 72-hr forecasted positions given in the FWC/JTWC warning provide a planning forecast, but must also be adjusted to consider a 275 n mi and 400 n mi average forecast error, respectively. When interpreting these average 24-, 48-, and 72-hr forecast errors, it should be remembered that these values are indeed averages. About half of the predictions must have had errors greater than this distance with extreme errors more than three times larger than the average (Somervell and Jarrell, 1970). Hence, an immediate plot of the warnings every six

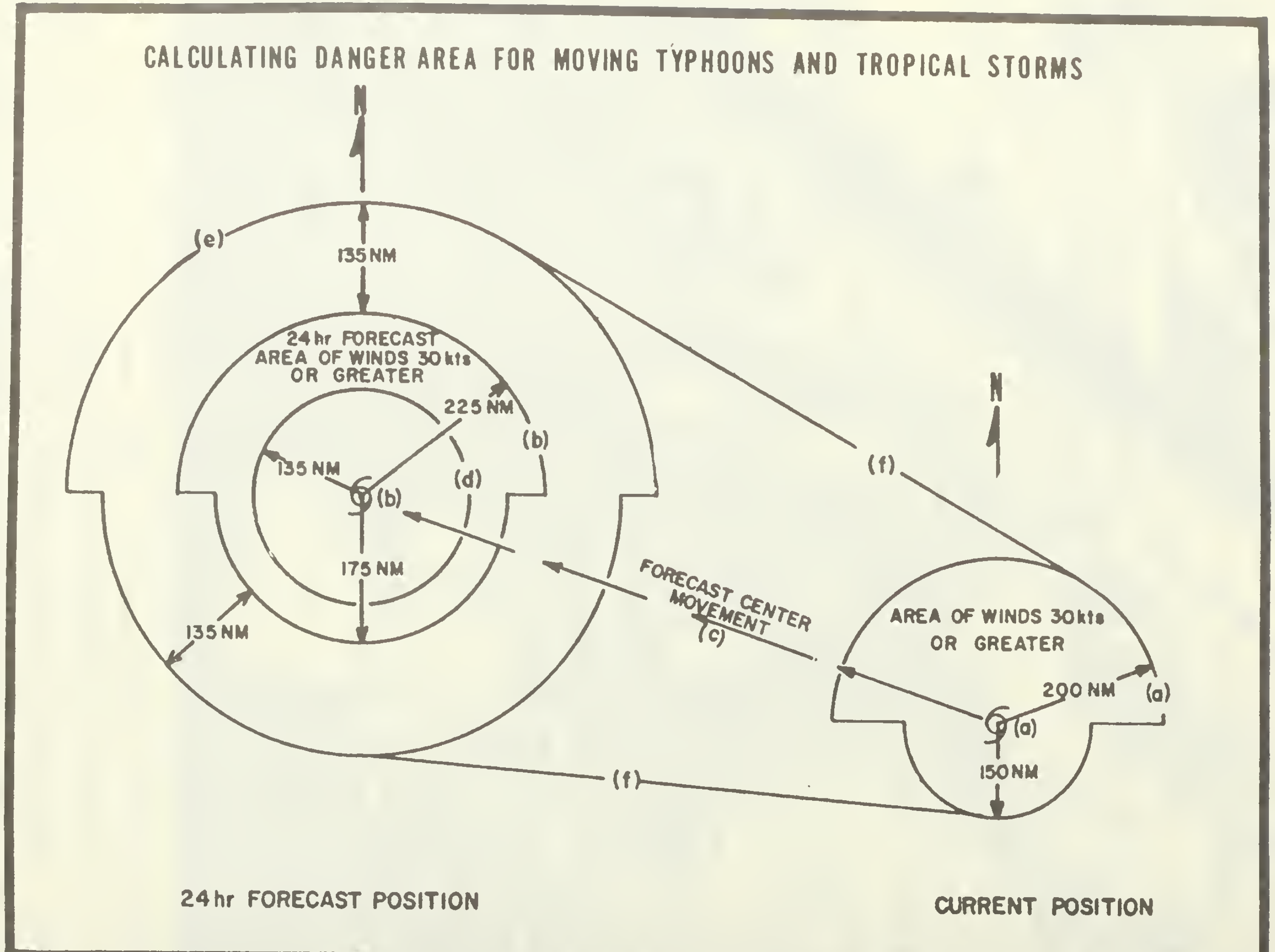

Figure 44. Method of calculating the danger area for moving typhoons and tropical storms. (From U. S. Commander Seventh Fleet, OPORD 201-(YR)).

hours should be standard procedure, as tracks are constantly updated and revised, and on occasion, radically changed (e.g., due to recurvature of the tropical cyclone).

ROHK advisories are also available to all ships in port at Hong Kong via the harbor net circuits.[1] As the tropical cyclone nears Hong Kong, local radar can yield an excellent fix of the center position if the cyclone is well defined.

Storm signals displayed in the harbor are as shown in Figure 45.

Once the decision has been made either to remain in port or to sortie and evade, it is the responsibility of the Senior Officer Present Afloat (SOPA) to advise all concerned as to his intended action in accordance with applicable OPORDS/INSTRUCTIONS. The message format is given in COMSEVENTHFLT OPORD 201-(YR), Annex W, Tab D to Appendix II.

7.2 EVASION

The key to a safe evasion must lie in the awareness that a threat to the harbor exists. Tropical cyclones which cross the northern portion of the Philippines into the South China Sea and finally strike the China coast have, in the past, had a relatively high probability (37-56% throughout the typhoon season, from Figures 23 through 29) of passing within the 180-n mi, over-ocean semicircle from Hong Kong. Sorties from Hong Kong must be made early in order to gain maneuvering room in the open ocean. Within 24 hours after a tropical cyclone crosses the Philippine Islands, although still a great distance from Hong Kong, swells can be generated that can severely

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[1] ROHK advisories may use the Beaufort wind force scale. A conversion table from the Beaufort scale to knots is given in Appendix C.

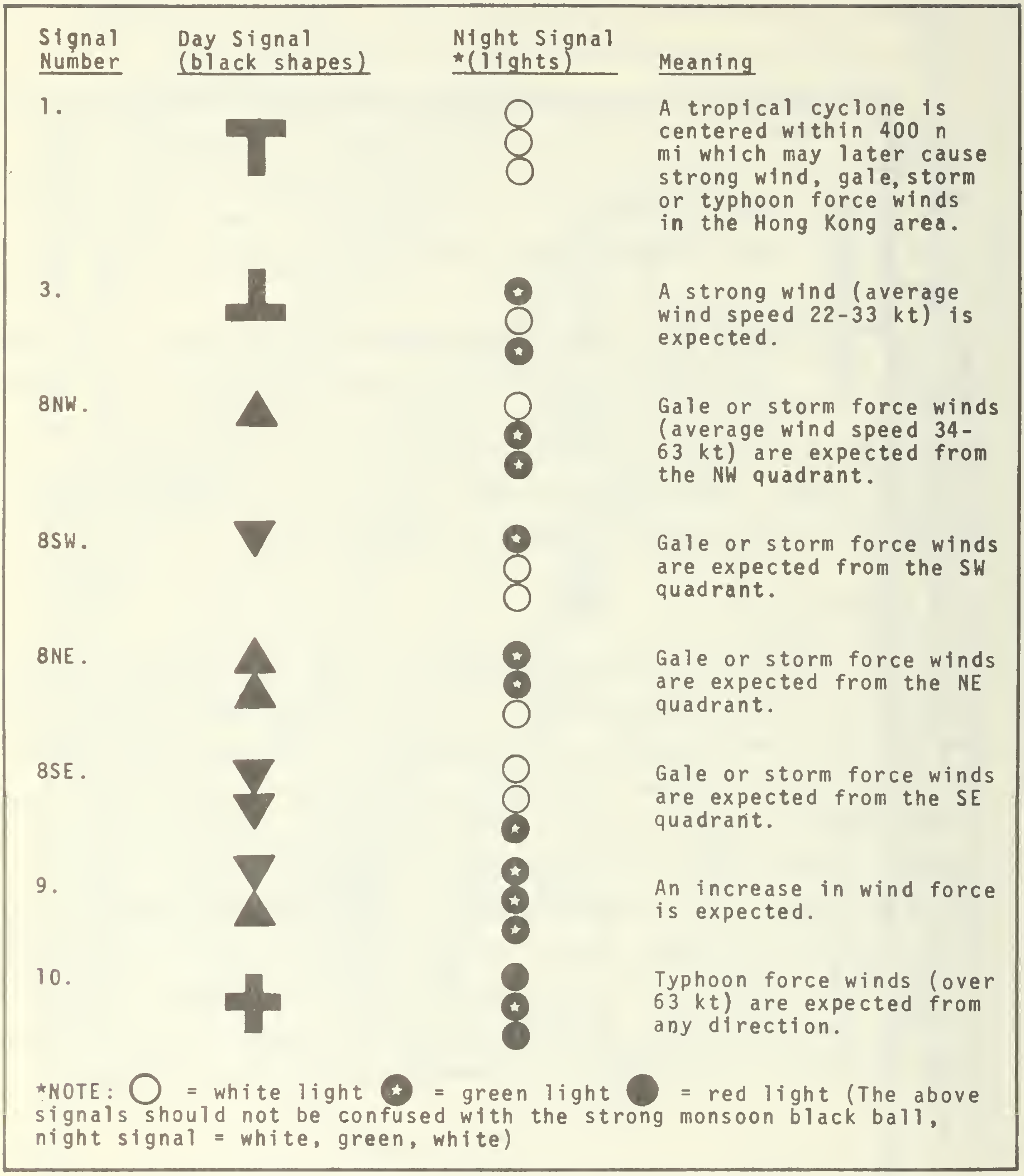

Figure 45. Hong Kong storm signals.

hamper a ship's speed-of-advance (Heywood, 1950). In the case study of Typhoon ROSE, even with the center of the storm 100 n mi south of Hong Kong, maximum seas in excess of 30 ft were observed by a wave recorder at Waglan Island (at the eastern approach to the harbor). These seas were measured approximately 14 hours before Typhoon ROSE struck the China coast just outside the harbor! Consequently, sortie action even 14 hours prior to the closest point of approach (CPA) to Hong Kong of Typhoon ROSE, with 30-ft seas as the entrance to the harbor, would have been very hazardous to say the least.

Decisive action must be taken early! Recalling all hands or enough critical personnel to sortie and clear the harbor is an extremely important part of getting out of Hong Kong harbor in time to evade. The heavy swells produced at the entrance to the harbor as a result of a typhoon crossing into the South China Sea can make a late sortie extremely dangerous.

The Royal Navy utilizes the following criteria for berthing and evasion as described by LCDR Morrice, Royal Navy, Base Meteorological Officer, Office of the Commodore-in-Charge, Hong Kong (Morrice, 1973b):

1. Introduction

The Royal Navy does not consider Hong Kong a suitable haven under typhoon conditions. The normal Naval policy is for warships of frigate displacement and above to put to sea in sufficient time for adequate evasion to be possible. Smaller units (patrol craft and coastal minehunters) normally secure to buoys in Victoria (Hong Kong) Harbour.

2. Alongside Berths

It is a matter of policy that no HM Ship remains alongside. The quay walls in the Naval Basin are considered too low because of the possibility of storm surge reinforcing high tides.

Experience has shown that the sea in Victoria Harbour becomes very confused with short steep waves. There is photographic evidence that the quay walls can be awash under typhoon conditions. Serious bumping with major damage and capsize resulting are considered very real consequences of staying alongside.

3. *Naval Buoys (See Figure 3)*

Numbers 1 and 2 Naval buoys are up to the standard for typhoon moorings and may be occupied at the discretion of Commodore Hong Kong by ships up to 600' in length; however, they invariably have to be vacated for use by the resident RN Patrol Craft. Numbers 3 and 4 buoys are only suitable for Patrol Craft or ships of CMS (coastal minesweeper) size in Typhoon conditions.

4. *Government Buoys (See Figure 3)*

Buoy B28 is normally used as a Patrol Craft typhoon mooring and as such may have to be vacated at an early stage. Buoys A1, A2 and A3 are not typhoon moorings. Buoys A4-A40, A43 and A44 are classed as special typhoon moorings for ships up to 600' in length. Buoys B5-B9, B11, B13-B22, B25, and B26 are classed as special typhoon moorings for ships up to 370' in length. All these buoys may be required by the Director of Marine who may order them to be vacated at any time. Their classification is subject to alteration at short notice.

5. *Anchorages (See Figure 3)*

Despite the quality of the bottom, anchoring in either Eastern or Western Anchorages is considered undesirable. In every major typhoon since the war a considerable number of ships have broken adrift from moorings and anchorages; these drifting hulks then present a deadly threat to ships in their path. The tragic loss of nearly 80 lives on the SS FATSAN in Typhoon ROSE (August 1971) was attributed to some extent to collisions with ships which had broken adrift and were not under command.

6. *Notice for Sea*

The nature of the coastline makes imperative an early departure if a real threat is in the offing. The effect of sailing on morale, always high in our considerations, must take second place under these conditions to the potential loss of, or severe damage to, operational units. During the period May-October, all HM ships in Hong Kong not under maintenance are required to be at 4 hours notice for sea and must be able to recall sufficient duty personnel to take the ship to sea within that time limit.

7. *Maintenance*

Ships under maintenance present a special problem, but here again the basic approach is the same. Repairs have to be boxed up to allow the ships to proceed to sea. There are only limited docking facilities available, and being commercial there is no guarantee that space will be available "on the day." In extremis, large ships have been towed to buoys and secured there to ride out the storm.

8. *Conclusion*

The overall policy is to "retain flexibility." This often entails decisions at an early stage when the magnitude of the threat is unknown and difficult to predict. However, adequate planning at this time can prevent the disastrous consequence of being unable to react in the way one would have wished to at a later stage. It is considered essential to take precautions and be prepared early, and then stand down should the threat diminish.

Normal Sequence of Events with a Slow Build UP

9. *See Figure 46*

The times given are for an 8-12 kt movement.

10. *A tropical cyclone in area A (Figure 46) (or even a potential development area in A) with a meteorological situation which indicates a possible movement towards Hong Kong:*

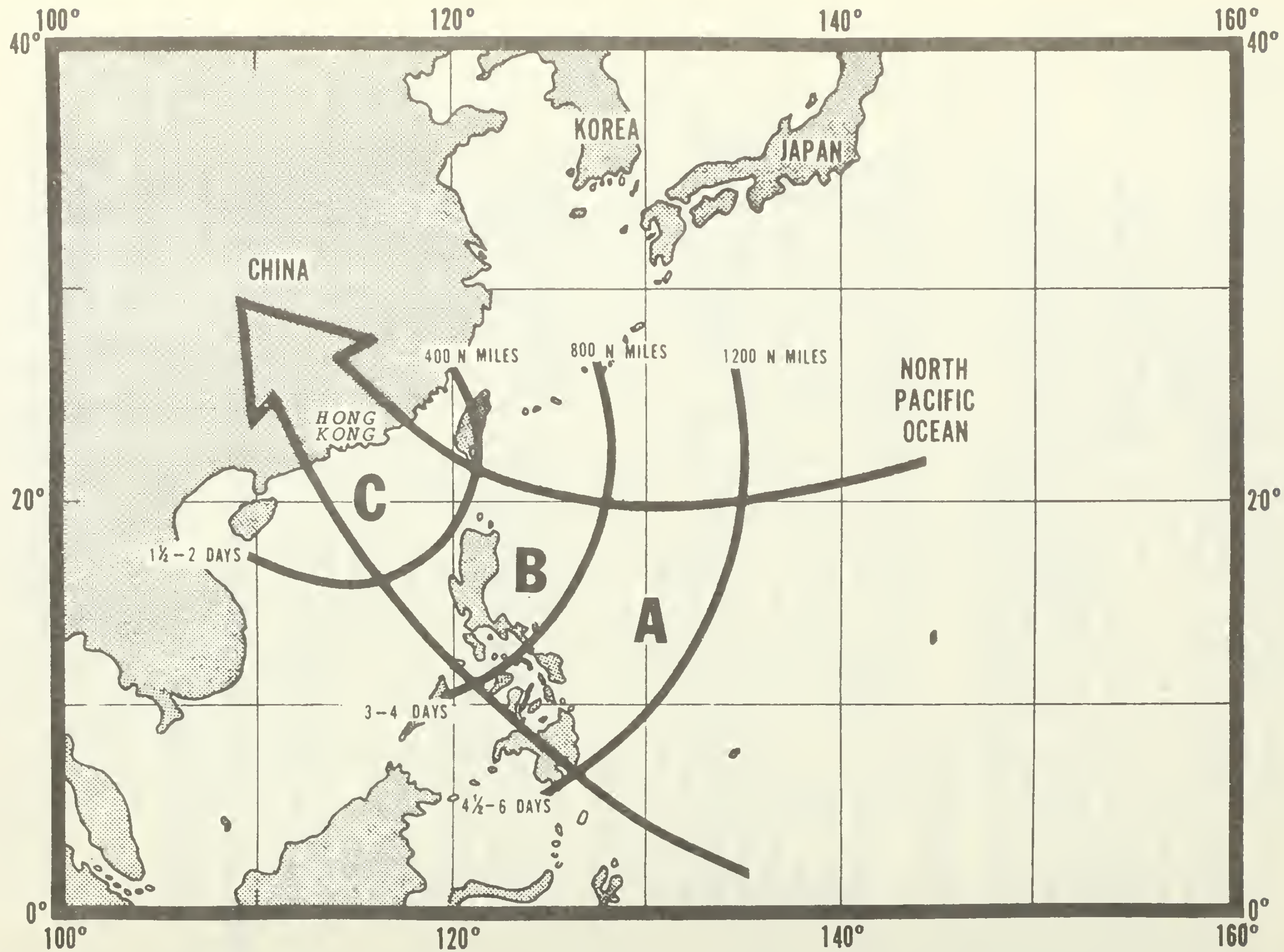

Figure 46. Tropical cyclone area of concern for Hong Kong. (From Morrice, 1973b.)

a. The material state of all ships will be reviewed.

b. Those fully operational will be warned that a situation may develop in 2-4 days which could necessitate sailing. This will be passed to liberty men with particular reference to any whose families have come to join them in Hong Kong.

c. Ships under maintenance will be considered more carefully. Any at 48 hours notice will require a decision, even at this early stage, if flexibility of action is not to be lost later.

11. *Tropical cyclone moves into area B. (See Figure 46)*

Should the meteorological situation still indicate a threat to Hong Kong, then ships under maintenance at 24 hours notice require a decision at this stage. Fully operational ships will start planning what course of action they will take should sailing be ordered. This aspect will be considered in more detail in a later section.

12. *Tropical cyclone entering area C. (See Figure 46)*

All the plans made during the previous stages now go into effect. Provided adequate action has been taken in the preceding days, flexibility to cope with the threat as it increases is retained. Ships intending to sail will proceed. The smaller units will secure to their typhoon buoys before winds locally reach 20 knots. Experience has shown that considerable difficulty can be encountered in securing with winds above this speed. At about the same time the Naval Base will be secured to "typhoon stations."

Avoiding Action at Sea

13. *The decision to sail, once taken, poses the new problem of the best course of action once at sea. The following section is based on the experience of the past few years. However, the commanding officer on the spot, with his detailed knowledge of ship and crew, must always make his own personal decision as the situation dictates.*

14. *The most common case is the tropical cyclone which crosses the northern Philippines or moves through the Bashi Channel on a west-northwest course. Should a passage close to Hong Kong be predicted and sailing ordered, the normal procedure is for the ships to sail southwest to cross ahead of the typhoon into the southern "safe" semicircle. Provided sailing is early enough, the winds and seas will not have got up, and good progress can be made as the prevailing winds will be northerly. Ship design must be considered however. In 1971 a Leander class frigate (with a low stern) experienced considerable difficulty in making way with stern wind and seas.*

15. *An uncommon situation would be a typhoon moving northeast towards Hong Kong having recurved over the western part of the South China Sea. Here ships would sail to the southeast to cross ahead of the typhoon's track. Wind and sea would be against the ship, and progress would be likely to be slow.*

16. *The most difficult case occurs when a typhoon moves north towards Hong Kong, and much depends on the meteorological situation. The "safe" semicircle lies to the west, but the coastline falls away to the west-southwest towards Hainan Island. To the east, in the "non-navigable" semi-circle, the coastline falls away to the ENE, and an Easterly course results in a steady increase in searoom. If recurvature towards the NE is likely, however, this course is most dangerous. However, should recurvature have a low probability, this may well be the best action to take.*

Noteworthy points regarding evasion at sea, stressed by Morrice, deal with three basic directions of threat by a tropical cyclone:

1. <u>A tropical cyclone approaching from the southeast after crossing Luzon, P.I.</u> This case occurs most often and requires two major criteria for evasion:

a. early sailing on a southwest track in order to cross well ahead of the tropical cyclone into the "safe" semicircle; and

b. a ship which rides fairly well in a following sea.

Crossing ahead of a typhoon is a serious matter not to be treated lightly. However, Somervell and Jarrell (1970) indicated that one of the most successful tactics in the Pacific involves crossing of the "T", that is, running downwind and down-sea ahead of the typhoon in order to cross the track and reach a position south of the storm.[2] It is emphasized that "crossing of the track" must be done <u>well in advance</u>. If not, the speed-of-advance of the ship may be hampered due to severe seas and swells, and the ship will be helplessly trapped in the direct path of the oncoming typhoon.[3] This tactic should not be attempted unless it can be managed outside the area covered by the expanded radius of 30 kt winds, i.e., the danger area (Somervell and Jarrell, 1970).

2. <u>A tropical cyclone approaching from the southwest</u> (after recurvature or development over the South China Sea). Again, early departure by a ship on a southeasterly track is the key in order to avoid as much as possible the head-on winds and seas that will significantly reduce any intended speed-of-advance. However, according to climatology (Figure 14), a tropical cyclone approaching from the southwest is less likely to occur.

3. <u>A tropical cyclone approaching from the south towards Hong Kong</u> (as in the Typhoon ROSE Case Study seen in Figure 38). This is undoubtedly the greatest threat to the harbor and unfortunately the most difficult to evade. There is

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[2] See Appendix D for a vivid accounting by CDR. F. L. Taylor, USN, Commanding Officer, USS AGERHOLM (DD-826) and of the AGERHOLM's ("Aggie's") experiences in evading Typhoon JOAN (Oct, 1970) in the South China Sea.

[3] See Appendix E for graphs of ship's reduced speed-of advance versus sea-state conditions.

little choice but to run an initial course of 090° True in order to obtain sea room in which to maneuver. This course is only acceptable, however, if recurvature towards the northeast is unlikely. Otherwise, a ship could be easily trapped in the path of the storm.

Any of the above decisions are difficult ones to make, but it is incumbent upon the local commander to make a decision and make it early.

7.3 REMAINING IN PORT

The following problem areas and considerations should be taken into account if the decision is made to remain in the harbor (which would apply to smaller ships, such as patrol craft or minesweepers, unable to outrun and evade at sea, or those ships unable to put to sea):

1. The possibility exists, at the discretion of the Commodore-in-Charge, of having to vacate the typhoon buoys on short notice for a less desirable spot in Western Anchorage.

2. The danger of ships broken adrift and out of control doing considerable damage in the tight quarters of the harbor is a threat.

3. Securing to buoys should be done before winds reach greater than 20 kt locally in order to prevent undue difficulty in securing. Note from Section 4 (Table 1) on the tropical cyclone climatology for Hong Kong that a tropical cyclone bearing 180° (170°-190°) from Hong Kong (due south) on the average will produce winds in the harbor of greater than or equal to 22 kt at a mean distance of 242 n mi!

4. The holding action of the bottom in the anchorages, although good, can not be expected to prevent dragging in winds

of typhoon intensity. In the case study of Typhoon ROSE, the USS REGULUS (AF-57) experienced extreme anchor drag prior to grounding, even though steaming to the anchor. Figure 47 provides a rough means to determine required steaming to the anchor to ease the strain. However, it should be cautioned that the use of engine power when the ship is yawing severely may only accentuate the yaw and worsen the situation instead of easing it (Crenshaw, 1965). Shipboard radar should be used to establish fixes and obtain relative positions to determine the amount of anchor drag encountered.[4]

5. Storm surge effects as a result of a typhoon moving inland may result in the increase of the mean water level of 2 to 3 ft above normal. This increase may be as high as 6 ft above normal with storm surge coinciding with high tide and strong southeasterly winds.

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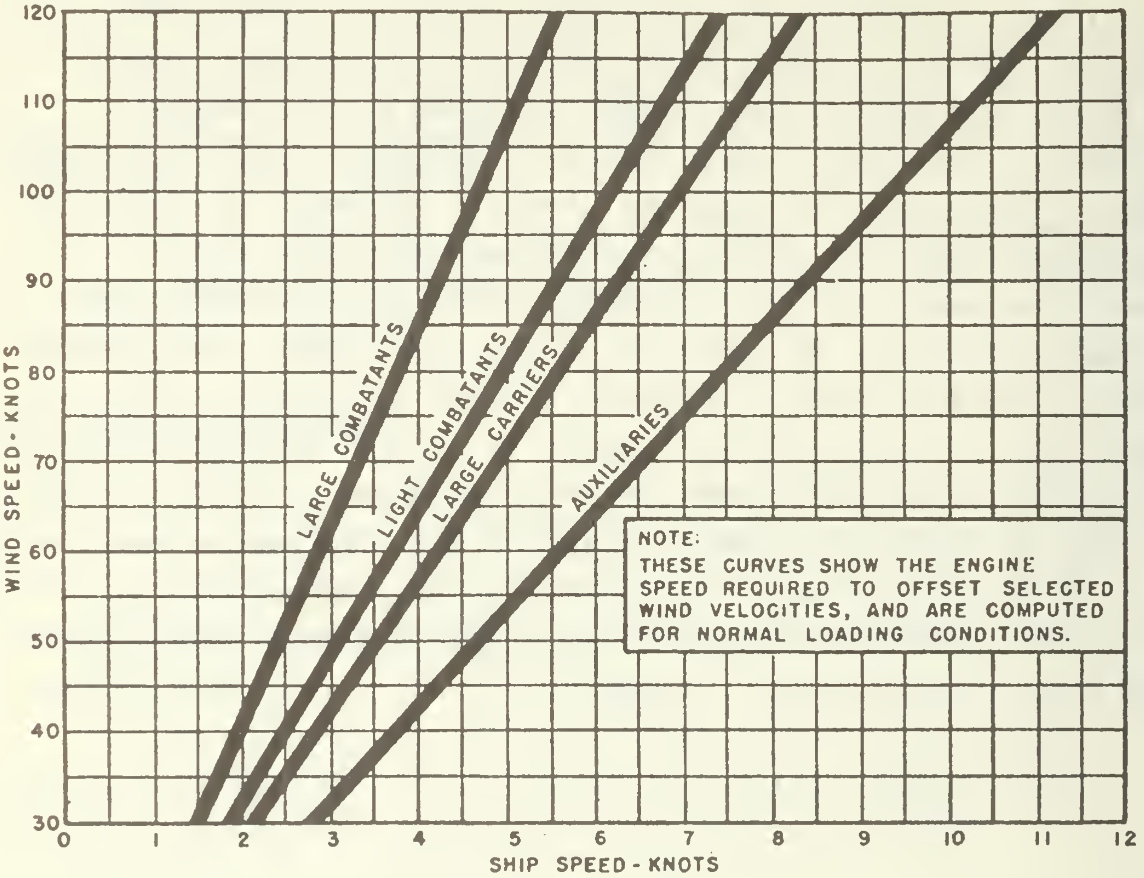
[4]COMSEVENTHFLTINST 5000.1H (dated 29 Feb 1972), Annex W, Heavy Weather Plan for SOPA Instructions, Hong Kong, is included in Appendix F. Additionally, for a more detailed description on securing for heavy weather, the Heavy Weather Guide by Harding and Kotsch (1965) is recommended.



THE CURVES SHOWN WERE DEVELOPED USING THE BASIC FORMULA:

$$\text{WIND LOAD} = R_w A V^2$$

WHERE R_w IS EQUAL TO WIND FRICTION FACTOR. (R_w IS GENERALLY TAKEN AS 0.004.)
V IS EQUAL TO WIND VELOCITY IN KNOTS.
A IS EQUAL TO PROJECTED AREA ABOVE THE WATERLINE IN SQ. FT.

THREE SETS OF CALCULATIONS WITH VARYING R_w WERE USED. THE PLOTTED VALUES ILLUSTRATED REPRESENT THE MEAN OF THESE VALUES.

Figure 47. Engine speed vs. wind velocity for offsetting force of wind. (From Crenshaw, 1965.)

8. CONCLUSION

This study of Hong Kong harbor as a possible typhoon haven must concur with previous conclusions that the harbor can not be designated a "safe" haven in time of severe winds and waves associated with the passage of tropical cyclones. Previous results, as stated in COMSEVENTHFLT INST 5000.1H, Annex W, dated 29 Feb 1972, readily indicate that "... it is considered that Hong Kong is not a suitable haven for Seventh Fleet units." This is also in agreement with the findings of the British, that "the Royal Navy does not consider Hong Kong a suitable haven under typhoon conditions."

The first step to making a safe evasion is in recognizing that a potential threat to the port of Hong Kong exists, based on current tropical cyclone warnings (from U. S. FWC/JTWC, Guam) and a knowledge of past tropical cyclone tracks that have affected Hong Kong, as (given in the climatology and statistics) presented in section 4. Smaller ships, such as minesweepers or patrol craft, unable to outrun and evade at sea, or those ships unable to put to sea should be thoroughly familiar with the potential problems of remaining in port as outlined in paragraph 7.3. It is recommended that all other Fleet units should take early decisive action to clear Hong Kong harbor and evade at sea (para. 7.2).

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APPENDIXES

APPENDIX A

PORT FACILITIES

1. *PILOTAGE (From Director of Marine, 1971)*

Although pilotage is not compulsory in the port, pilots licensed by the Pilotage Board are available to board ships at either entrance on request. The Hong Kong Pilots Association, with 22 licensed Hong Kong Harbor pilots and five apprentice pilots as its members, provide pilotage services. Pilots generally board inbound ships using the eastern entrance in the vicinity of the Lei Yue Mun turning buoy (latitude 22° 16.4' north, longitude 114° 15.3' east) and disembark at the same point from outward-bound ships.

At the western entrance, pilots embark and disembark to the west of Green Island.

It is a contravention of regulation 3(1) of the Merchant Shipping (Control of Ports) Regulations, 1953 as amended by the Merchant Shipping (Control of Ports) (Amendment) Regulations, 1965, for any vessel to pick up or discharge a pilot within a distance of 7.5 cables from the center of either the Lei Yue Mun Pass or Sulphur Channel.

2. *TOWAGE FACILITIES (From Marine Dept. Hong Kong, 1970)*

Commercial towage facilities are as listed in the following paragraph. Masters of vessels who may be required to shift berth in the event of a tropical cyclone affecting the Colony, should bear in mind that the services of tugs are at a premium immediately before and following the passing of a tropical cyclone. Tugs are then generally employed in shifting vessels to and from dockyards. Calls for towage assistance should therefore be kept to a minimum and made only in case of real emergency as when life and ships are endangered.

Operational Tugs:

Name	B.H.P.	Bollard Pull (Tons)	Owner/Manager
Whampoa	1160	18	Hong Kong & Whampoa Dock Co. Ltd.
Hung Hom	1600	25	Hong Kong & Whampoa Dock Co. Ltd.
Hong Kong Docks	1000	10.75	Hong Kong & Whampoa Dock Co. Ltd.
Edith	440	5.1	Hong Kong & Whampoa Dock Co. Ltd.
Taikoo	1600	30	Taikoo Dockyard and Engineering Co. Ltd.
Taikoo Shun-O	1000	10.75	Taikoo Dockyard and Engineering Co. Ltd.
Wanchun	1000	12	Taikoo Dockyard and Engineering Co. Ltd.
Taikoo Wan Yee	1700	24	Taikoo Dockyard and Engineering Co. Ltd.
Golden Cape	1900	18.5	Mollers Limited.

3. *TYPHOON MOORINGS (From Marine Dept., Hong Kong, 1970)*

A. *General Classification*

In Hong Kong harbor the following moorings are, at present, approved for use as special typhoon moorings:

(a) "A" class for vessels not exceeding 600 feet (182.9 meters) in length.

A 4 to A 19, A 21 to 40.

A total of 36 moorings.

(b) "B" class for vessels not exceeding 370 feet (112.8 meters) in length.

B 5, B 7 to B 9, B 11, B 13, B 16, B 18 to B 22 and B 26.

A total of 13 moorings.

The above list is subject to amendment and up-to-date information may be obtained from the Port Control Office, Marine Department.

The distance between Government mooring buoys in Hong Kong harbor is 1,400 feet (426.7 meters) in the case of "A" class typhoon moorings and 1,000 feet (304.8 meters) in the case of "B" class moorings.

B. *Composition of Typhoon Moorings (From Marine Dept., Hong Kong, 1970)*

(a) "A" class typhoon moorings are comprised of two 9-fathom lengths of 3½ inches (8.9 cm) stud link cast steel cable, with a swivel fitted between the two lengths, secured to a 90-ton concrete sinker consisting of a 50-ton base block and a 40-ton saddle. The buoy fittings, cable, swivel and shackles are tested to a strain of 247 tons when new. They are inspected every twelve months and cables are turned end for end every alternate year. The minimum size of chain permitted, with weardown, is 3 inches (7.7 cm).

(b) "B" class typhoon moorings are of a similar composition except that the size of chain is 3 inches (7.7 cm) and the concrete block is 50 tons. Components are tested to 204 tons when new and the minimum size of chain permitted is 2½ inches (6.4 cm).

4. TYPHOON INSTRUCTIONS FOR FOREIGN WARSHIPS COMMODORE-IN-CHARGE, HONG KONG MEMORANDUM DATED 5 MAY 1967

1. This memorandum replaces my memo No. HK. 10/73/3 dated 14th May, 1966 which should be destroyed. It should be attached to the front of copies of Hong Kong General Order 0112 which remains unaltered.

2. Commanding Officers of Foreign Warships visiting Hong Kong during the Typhoon Season are requested to make themselves familiar with these Orders IMMEDIATELY upon ARRIVAL.

Commanding Officers of United States Warships are requested to return their copies to the Commanding Officer United States Ship acting as Senior Officer Present Afloat (ADMIN) before sailing; other ships are requested to return their copies to the Operations Room, H.M.S. TAMAR.

3. As the timings of any particular action may be dependent upon the berth occupied, the following brief notes on berths are designed to help the U.S.N. Senior Officer Present Afloat and the Commanding Officers to be ready for likely moves. It will be appreciated that orders to move may be received from the Commodore-in-Charge, Hong Kong, for those ships at Naval berths. (Paragraph 5 (a) (b)). Orders from the Director of Marine for those ships at commercial moorings not listed as requiring automatic vacation will be passed through the Commodore-in-Charge, Hong Kong.

4. Communications During Typhoon Sorties

a. As normal communication links cease to be available when Foreign Warships have sailed, such ships which intend to return to Hong Kong should maintain

constant watch on 4304 Kcs. (C.W.) with Hong Kong Naval Wireless (Call Sign GZO). Ships in company should arrange communication guards as requisite.

b. *Berthing instructions on return to harbor will be passed on this circuit and ships are requested to keep the Commodore-in-Charge, Hong Kong informed of their movements.*

c. *Small ships which remain in harbor should maintain constant watch on British Harbor Intercom (277.0 Mcs) with Hong Kong Naval Wireless (Call Sign FLAG).*

5. *Notes on Berths in Hong Kong Harbor in Typhoon Season.*

a.	*Alongside Berths in Naval Base*	*All must be vacated at discretion of the Commodore-in-Charge, Hong Kong in sufficient time to lift catamarans, etc.*
b.	*Naval Moorings (No. 1 to 4)*	*All these moorings are up to the standards for Typhoon Moorings and may be occupied at discretion of the Commodore-in-Charge, Hong Kong.*
c.	*Commercial A.1 to A.3, A.31. (Minimum cable size 2 3/4")*	*These are not Typhoon Moorings and Director of Marine requires them to be vacated within two hours of a Typhoon Signal other than 1 and 3 being hoisted. At such a time it may well be too late for ships to get clear to seaward.*
d.	*Commercial B.28, A.41, A.42.*	*These are similar to c. except that they*

		are Special Typhoon Moorings for R.N. Coastal Minesweepers and they are likely to be required as such any time after Typhoon Signal No. 1 is hoisted.
e.	<u>Commercial A.4 to A.16, A.19, A.21 to A.30, A.32 to A.34</u>. (Minimum cable size 3")	These are Typhoon Moorings for ships not exceeding 600 feet in length. Ships may be required by the Director of Marine to vacate these berths to provide room for dead ships from local shipyards.
f.	<u>Commercial A.35 to A.40</u>. (Minimum cable size 3")	These are Typhoon Moorings for ships not exceeding 600 feet in length but are reserved for berthing dead ships from Taikoo & Kowloon Dockyards and as such they would require automatic vacation on the hoisting of No. 1 Typhoon Signal. The Dockyards start moving promptly and nearly always before No. 3 is hoisted.
g.	<u>Commercial B.5, B.7, B.11, B.13, B.16, B.18, B.26</u>. (Minimum cable size 2 1/2")	These are Typhoon Moorings for ships up to 370 feet in length.
h.	<u>Commercial - Remaining Buoys</u>. (Minimum cable size 2")	Those are not Typhoon Moorings and must be vacated as in c.

5. TYPHOON ANCHORAGES (From Marine Dept., Hong Kong, 1970)

Junk Bay and the eastern approaches to Hong Kong harbor are not considered to be suitable areas in which to anchor during typhoons, and there is no longer any space available in Kowloon Bay for use

as a typhoon anchorage. The most popular anchorage during the passage of tropical cyclones is on or to the westward of Kellett Bank (latitude 22° 18' N., longitude 114° 06.5' E.) where the depth of water varies from 3 fathoms to 12 fathoms.

When anchoring for an impending tropical cyclone, ample cable should be paid out at once without waiting until the force of the storm is felt as paying out then tends to disturb the anchor. Ships should always have their second anchor ready for letting go and use it before the winds reach gale force.

New arrivals should ensure that the clamps and bolts securing the spare anchor are not corroded so that in the event of losing an anchor this spare unit can be shackled onto the remaining cable as soon as circumstances permit.

APPENDIX B

Figures B-1 through B-14 represent monthly and half monthly climatological tracks (March to December) of tropical cyclones in WESTPAC which at some time were of typhoon intensity. Twenty four years of tracks were used (1946-1969). (From Gray, 1970.)

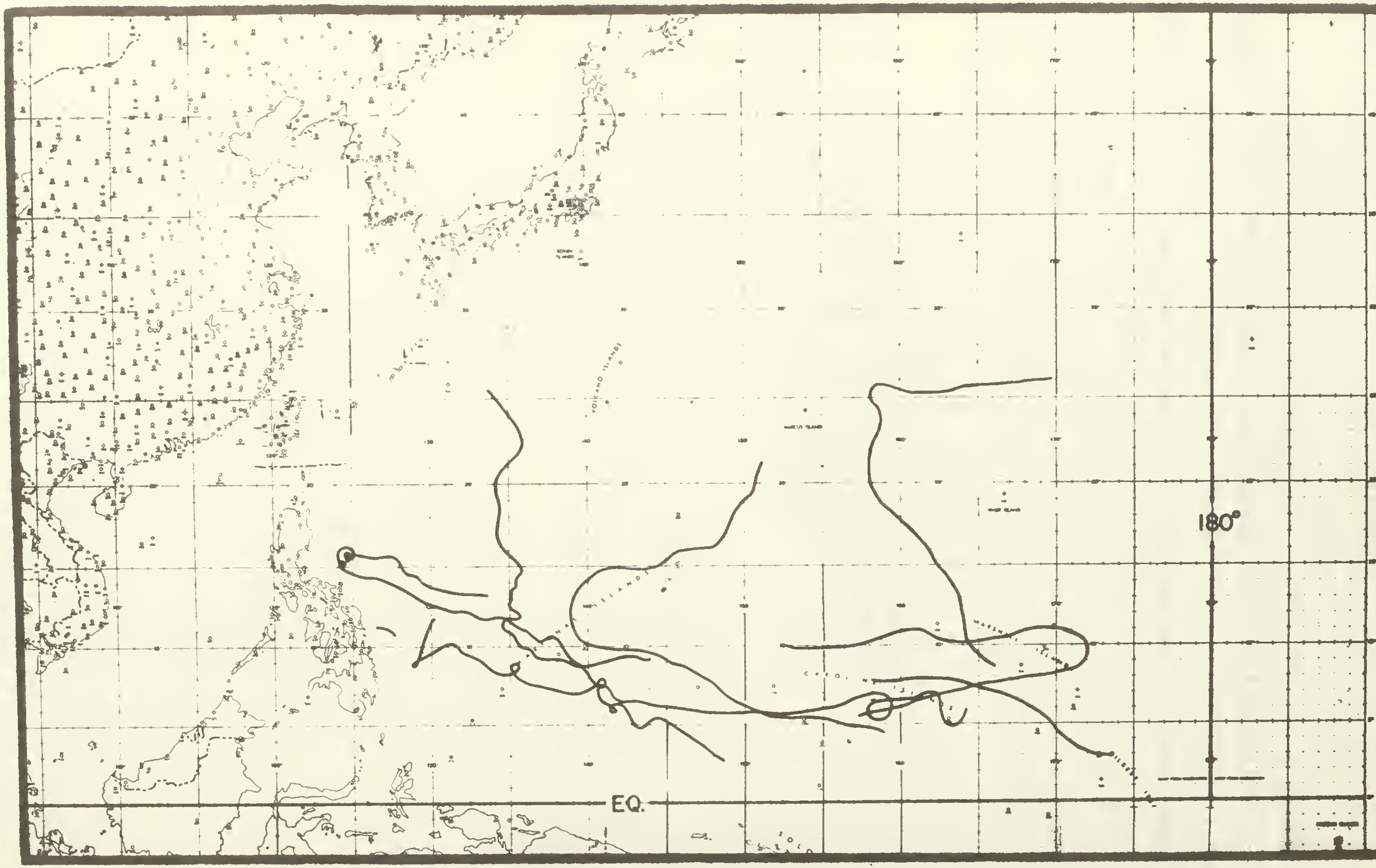


Figure B-1. March tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

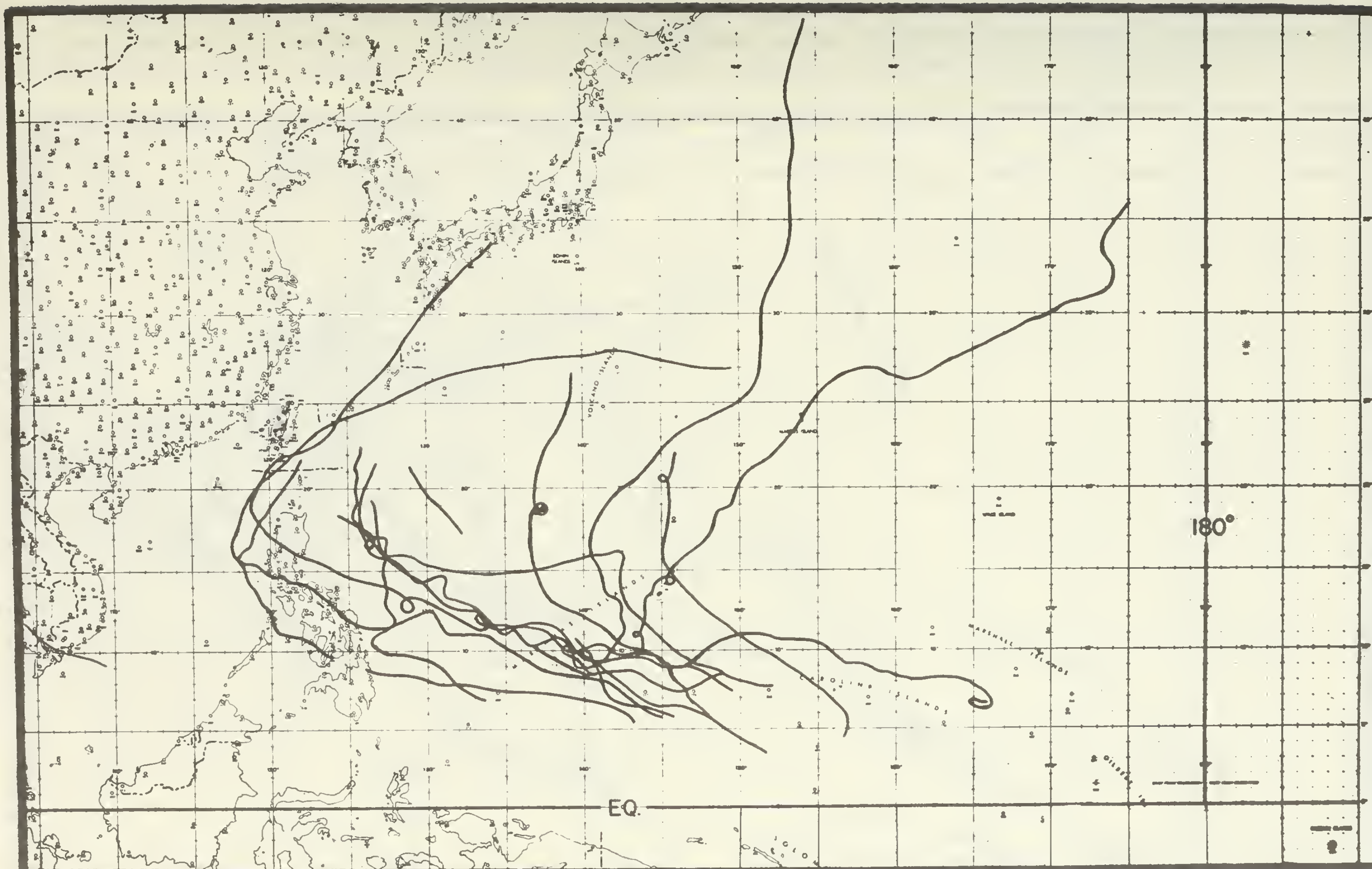


Figure B-2. April tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median data of their existence.

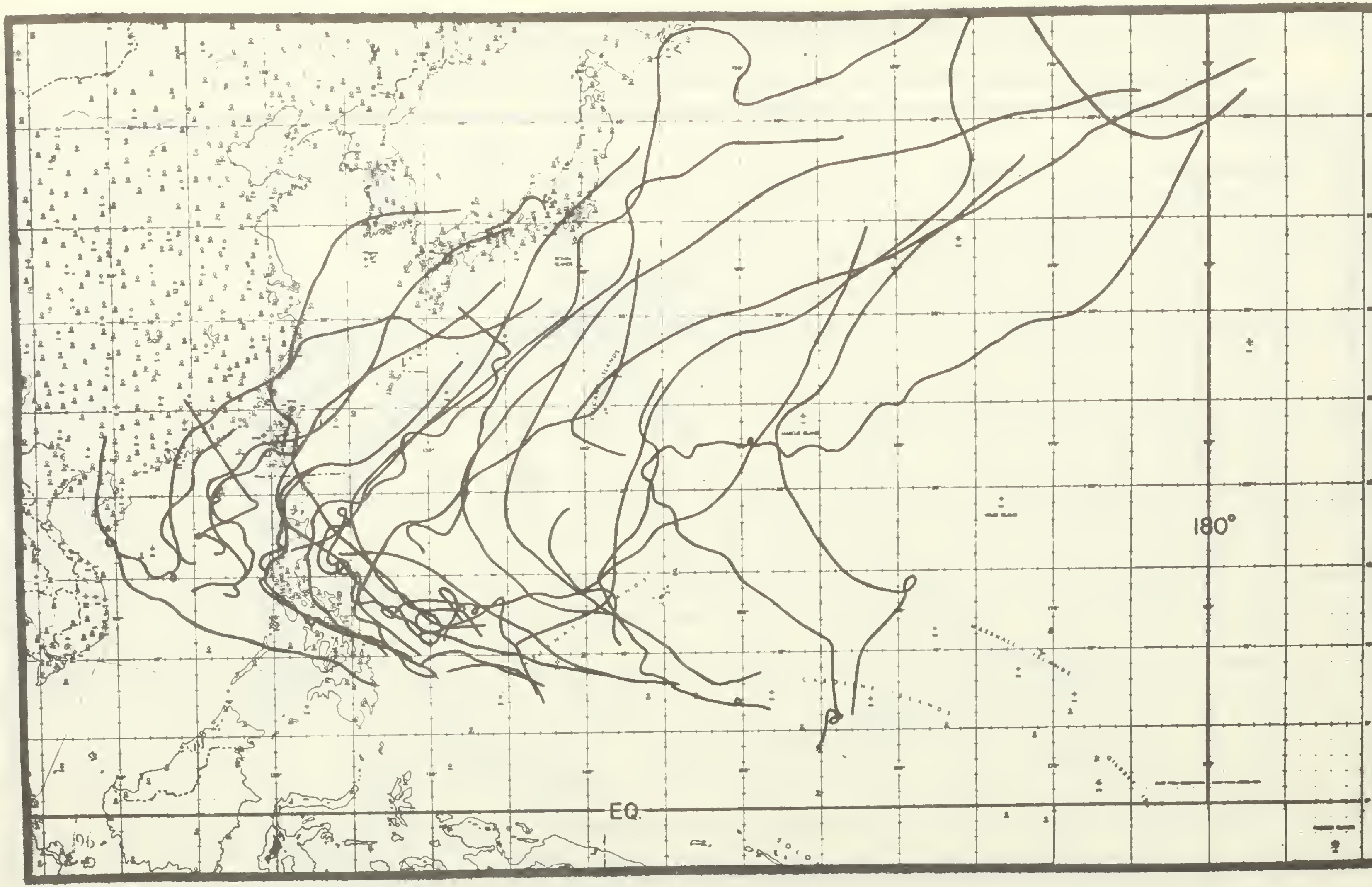


Figure B-3. May tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

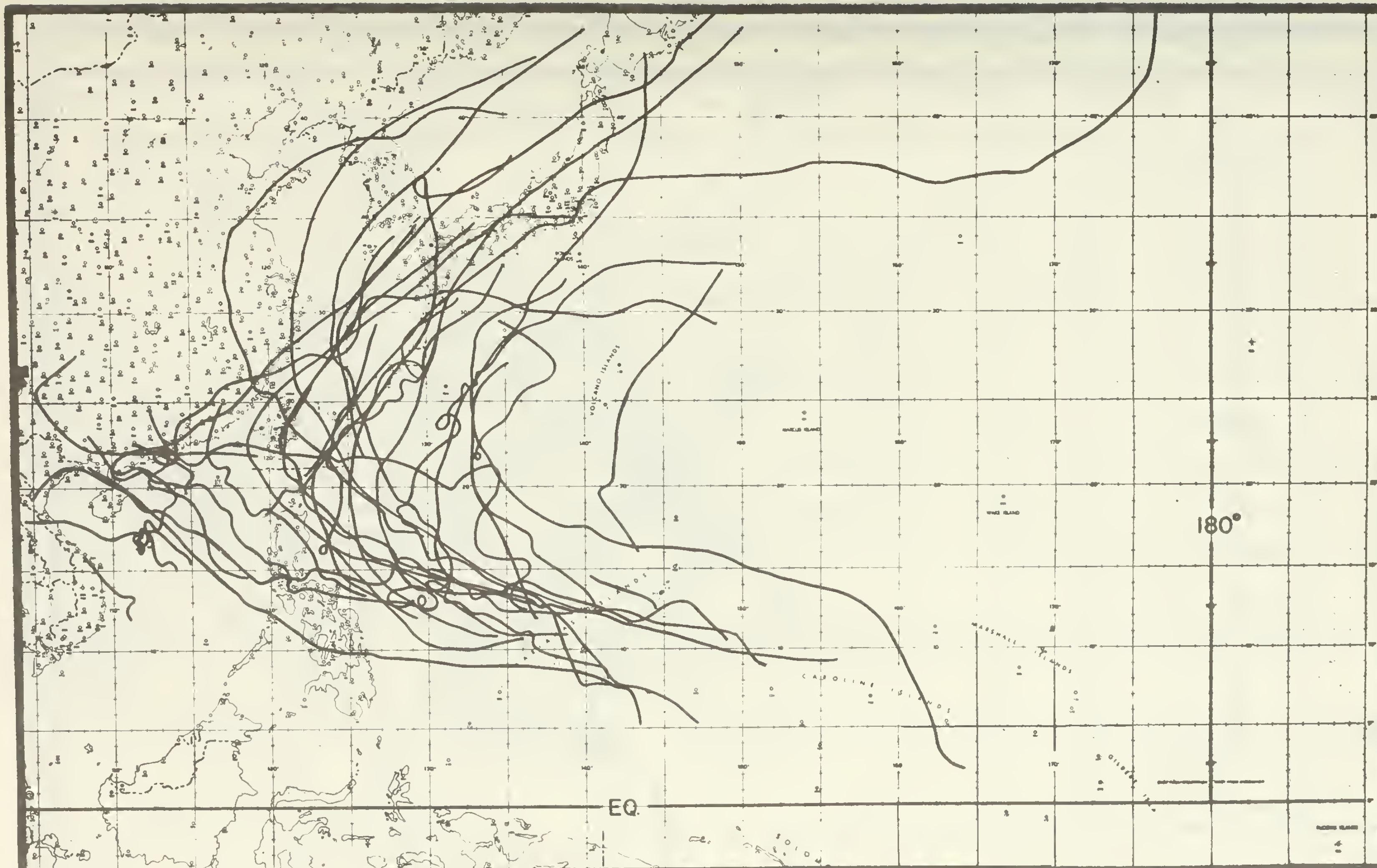


Figure B-4. June tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

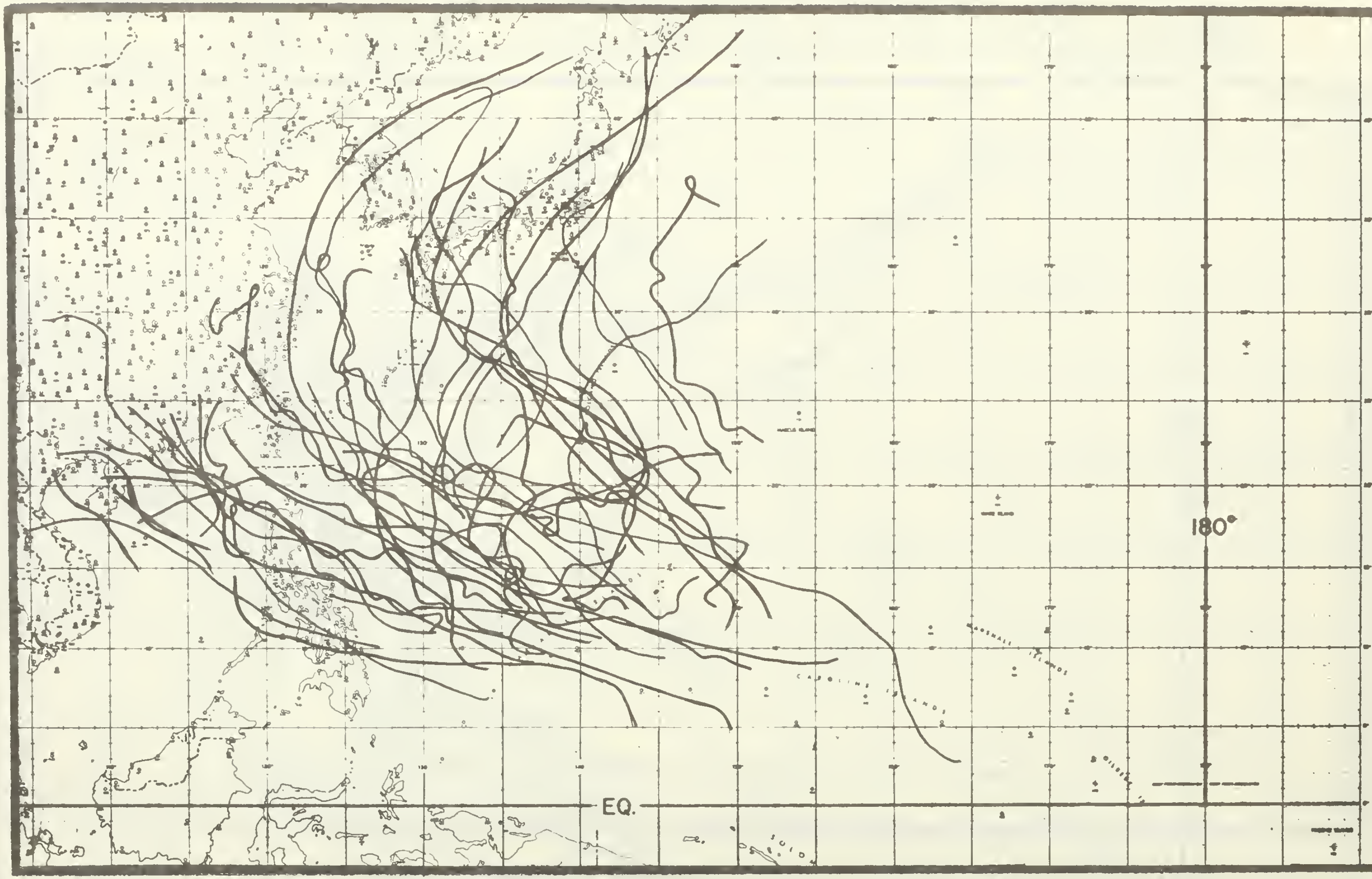


Figure B-5. July (first half) tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

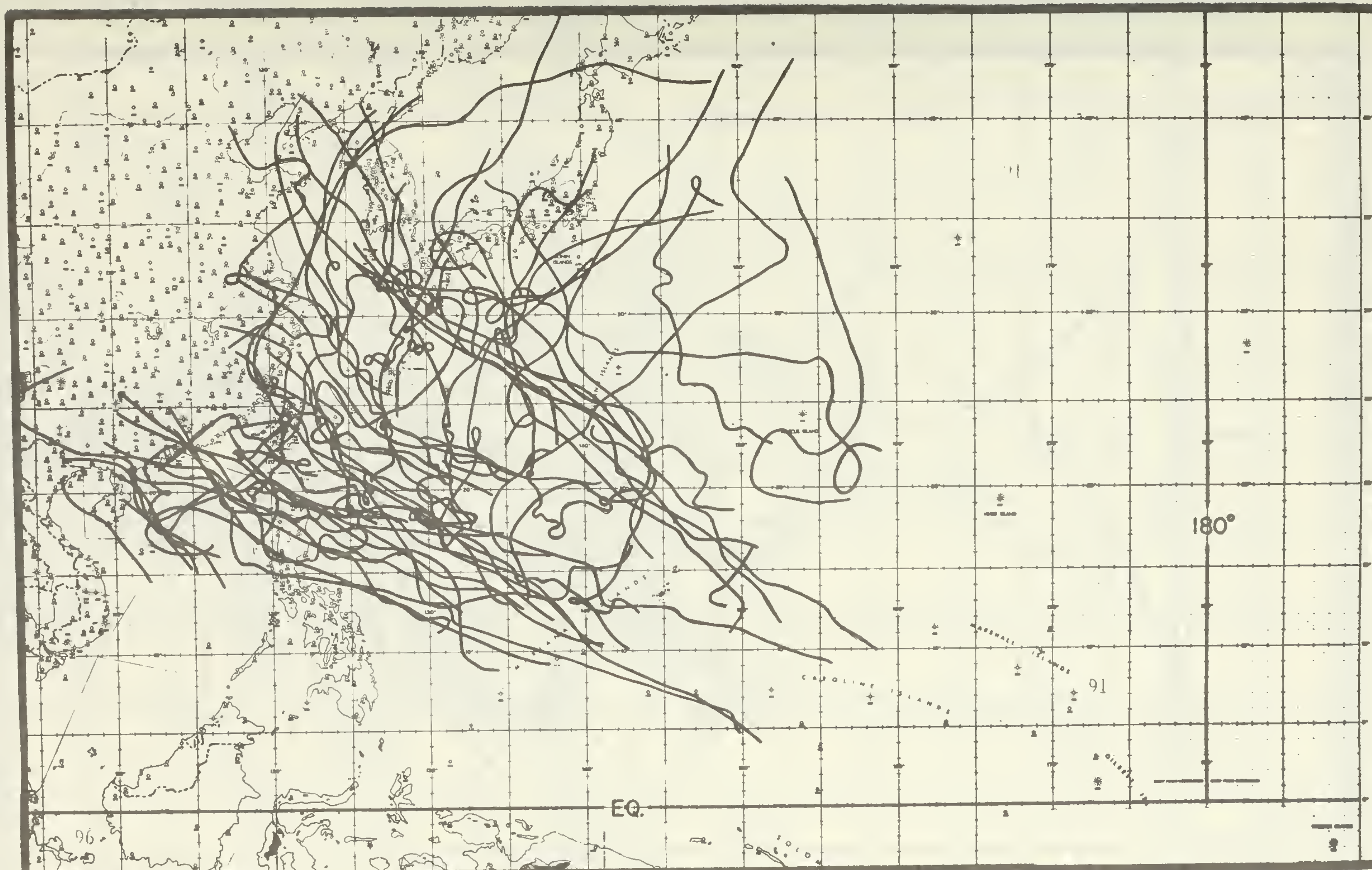


Figure B-6. July (second half) tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

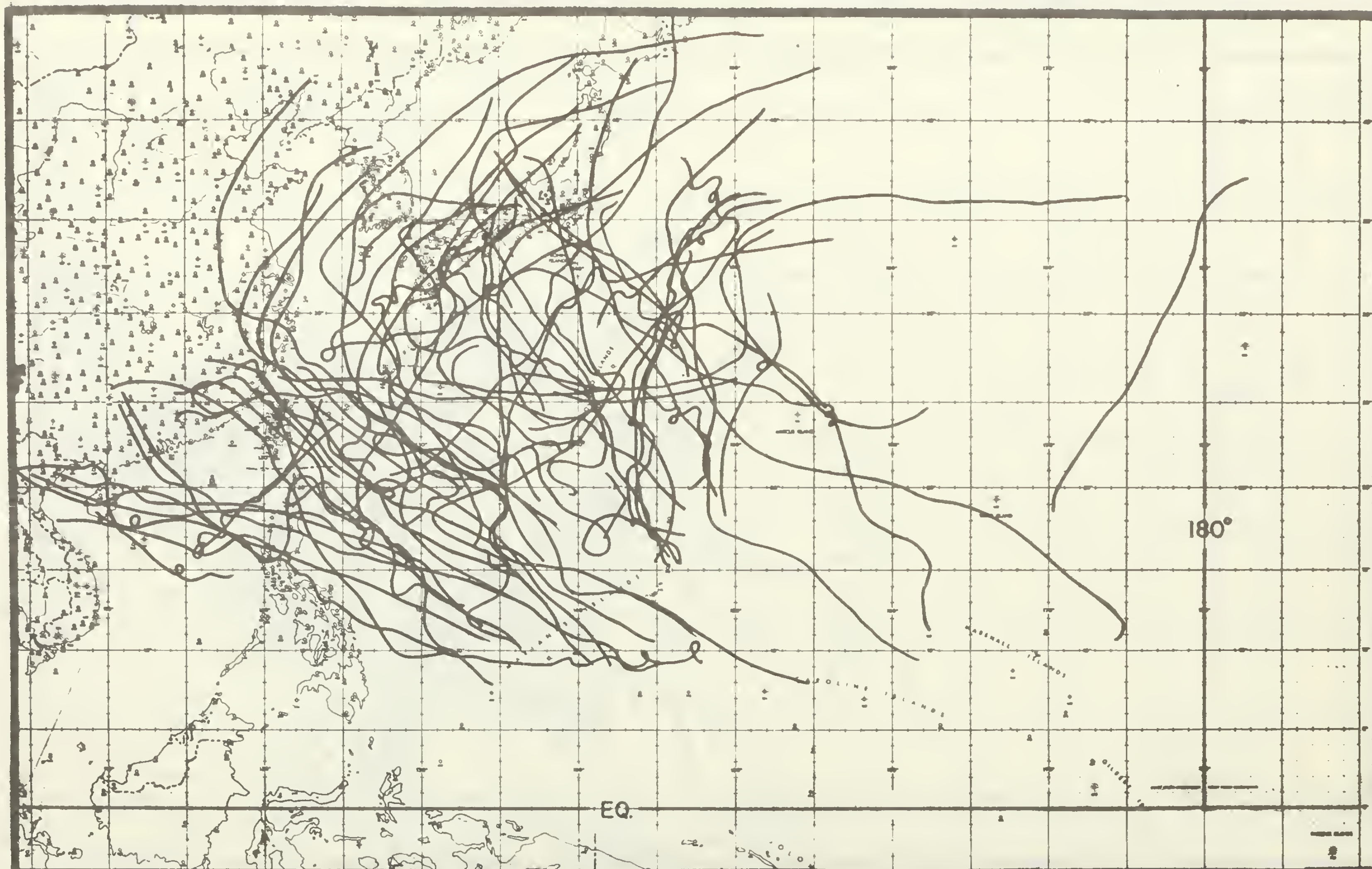


Figure B-7. August (first half) tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

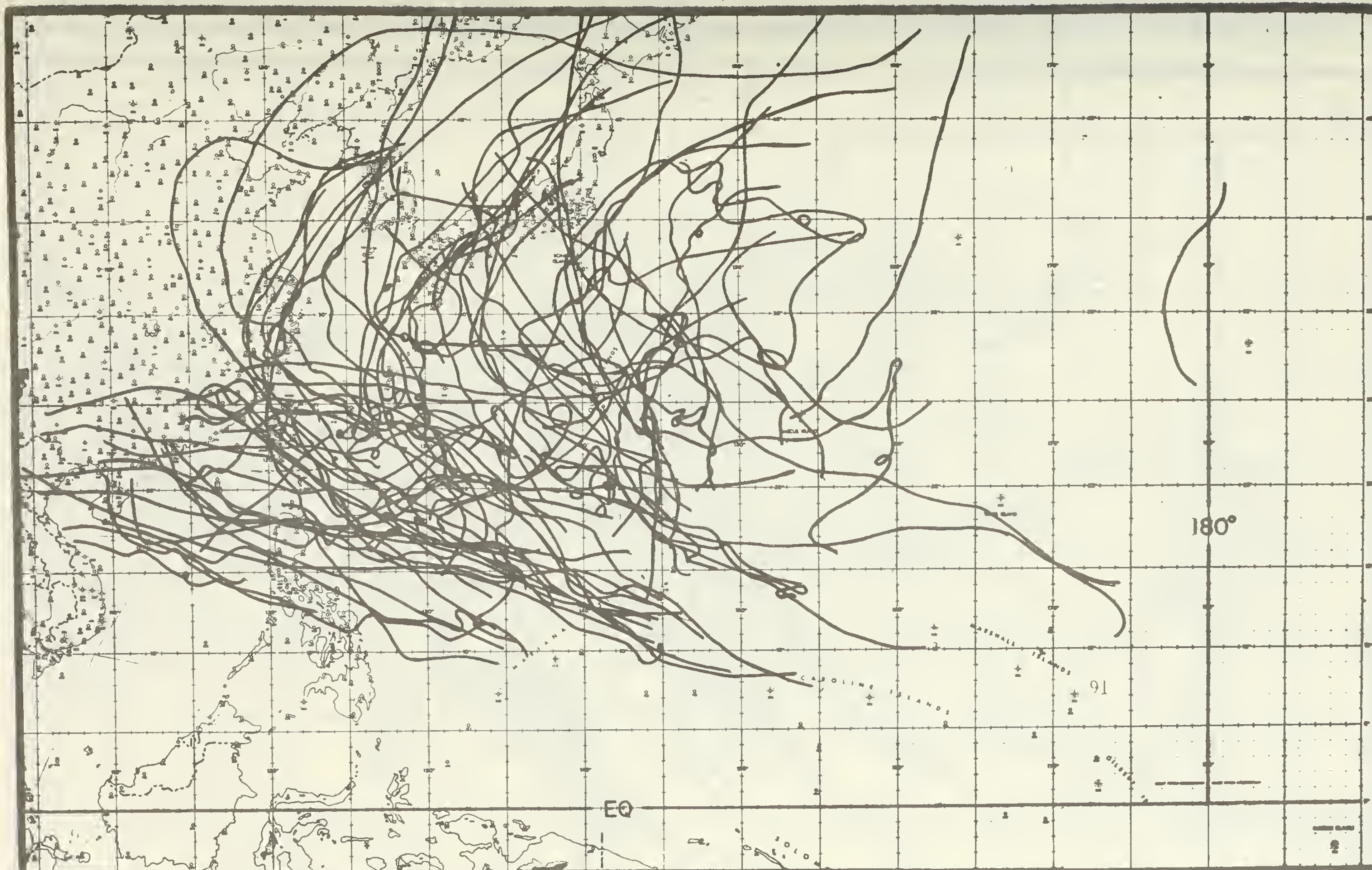


Figure B-8. August (second half) tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

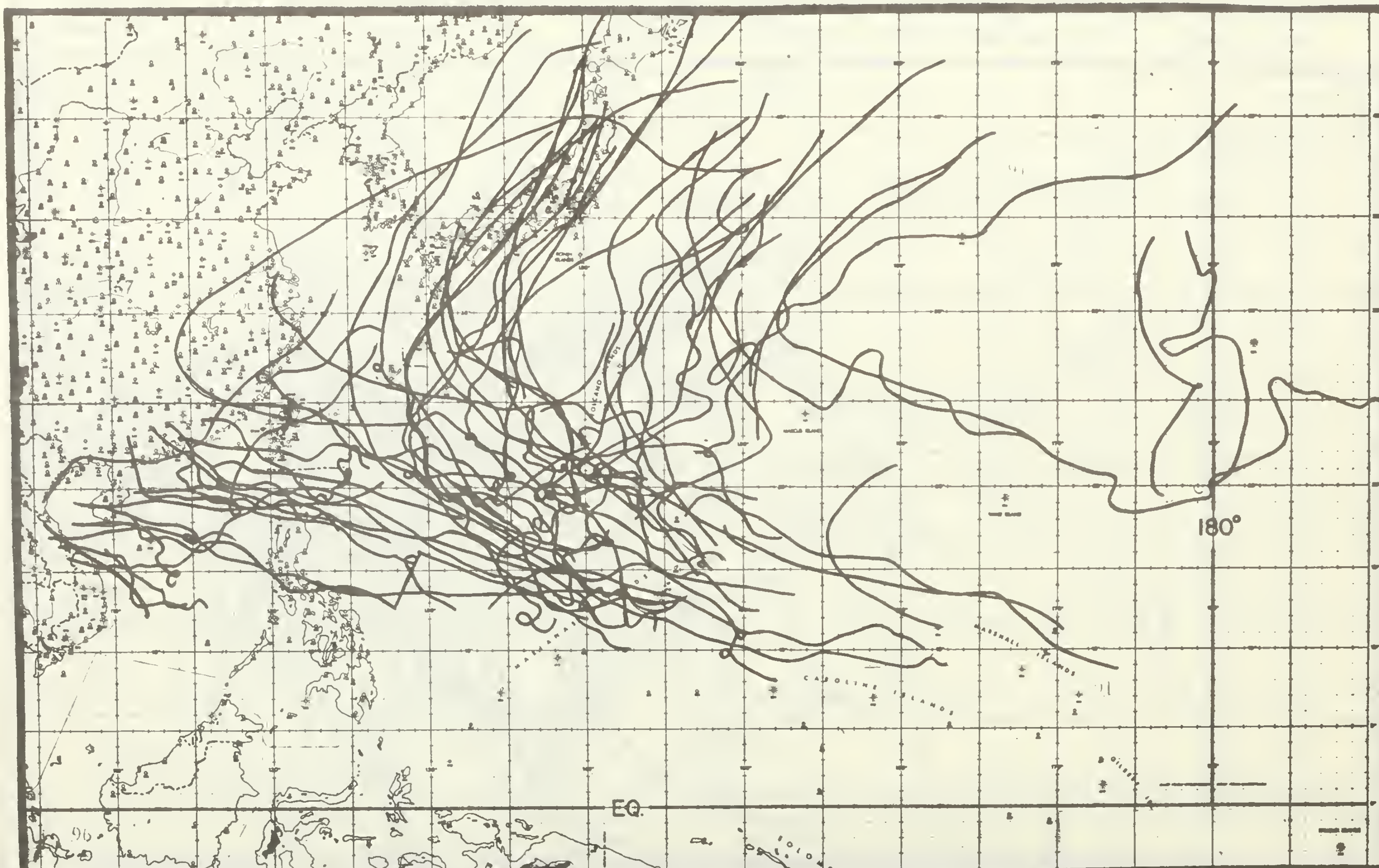


Figure B-9. September (first half) tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

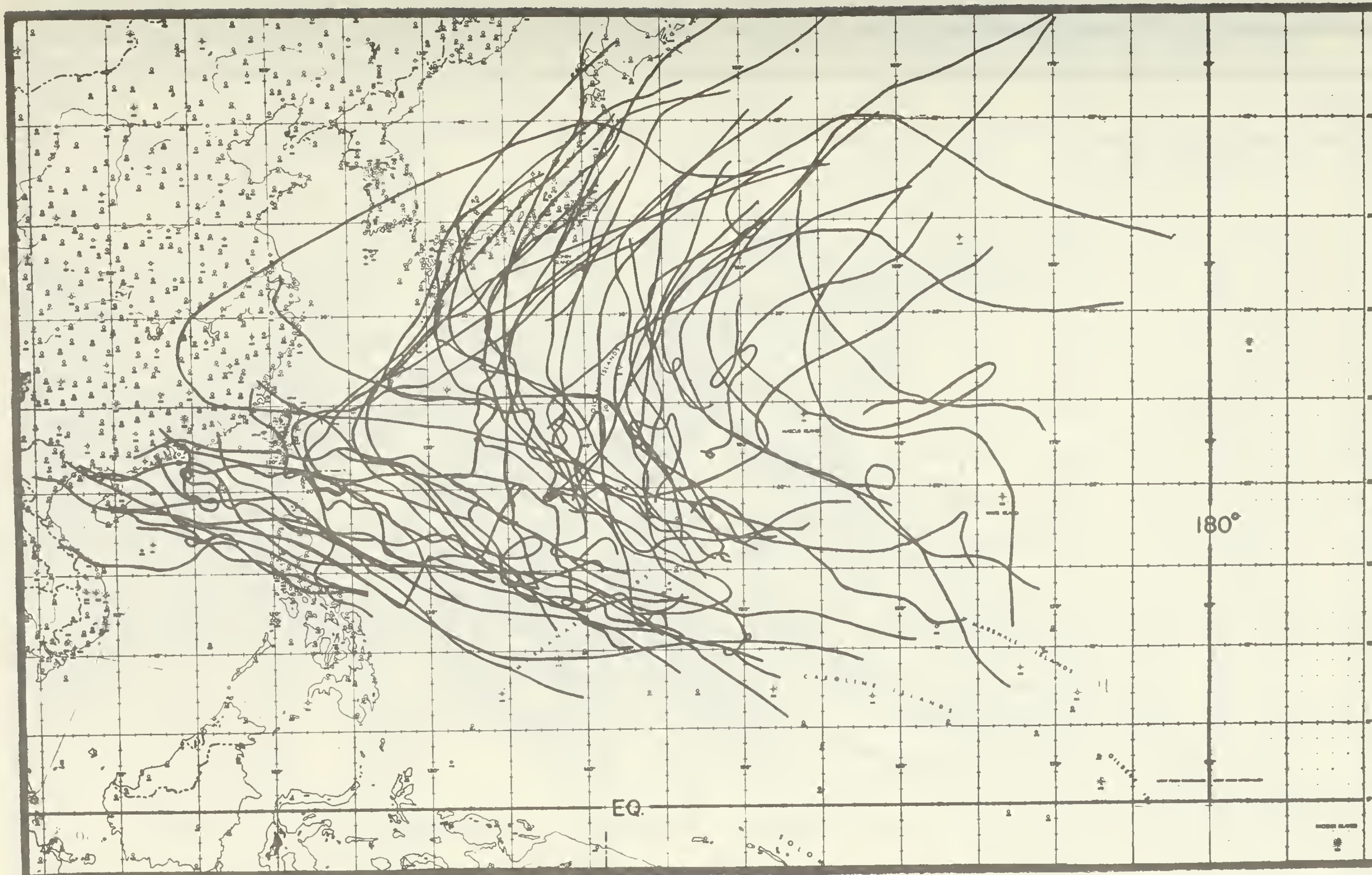


Figure B-10. September (second half) tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

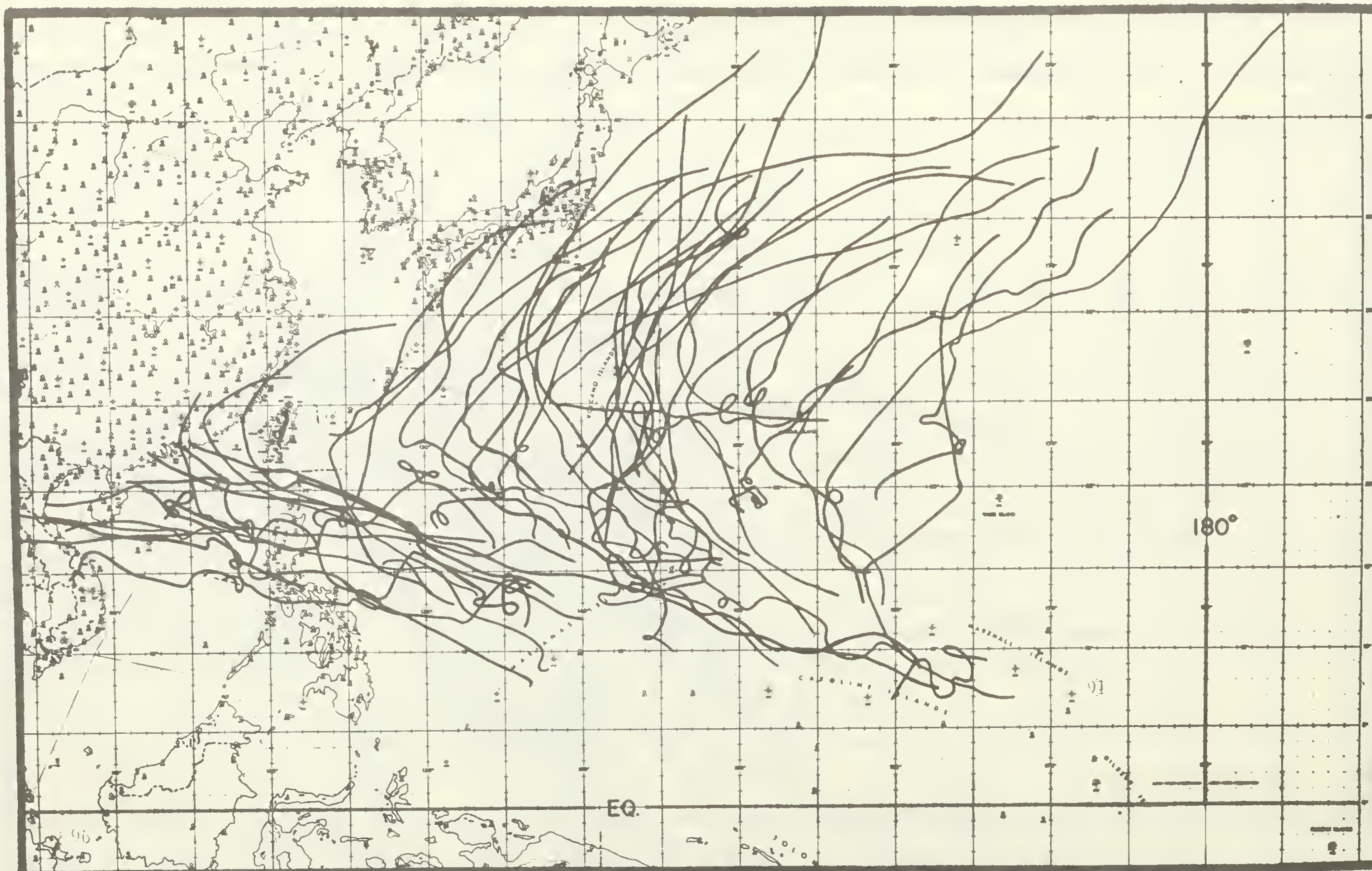


Figure B-11. October (first half) tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

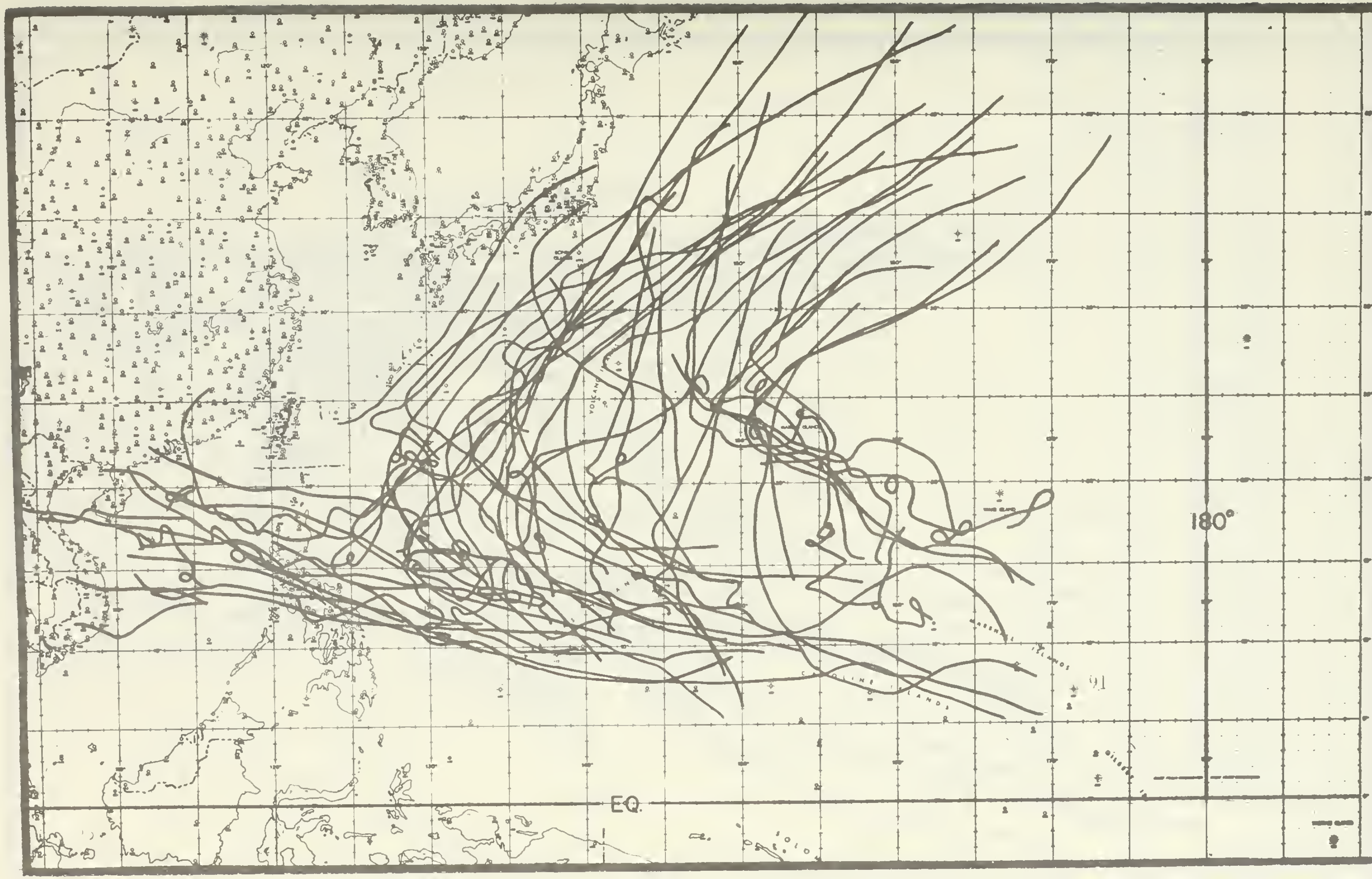


Figure B-12. October (second half) tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

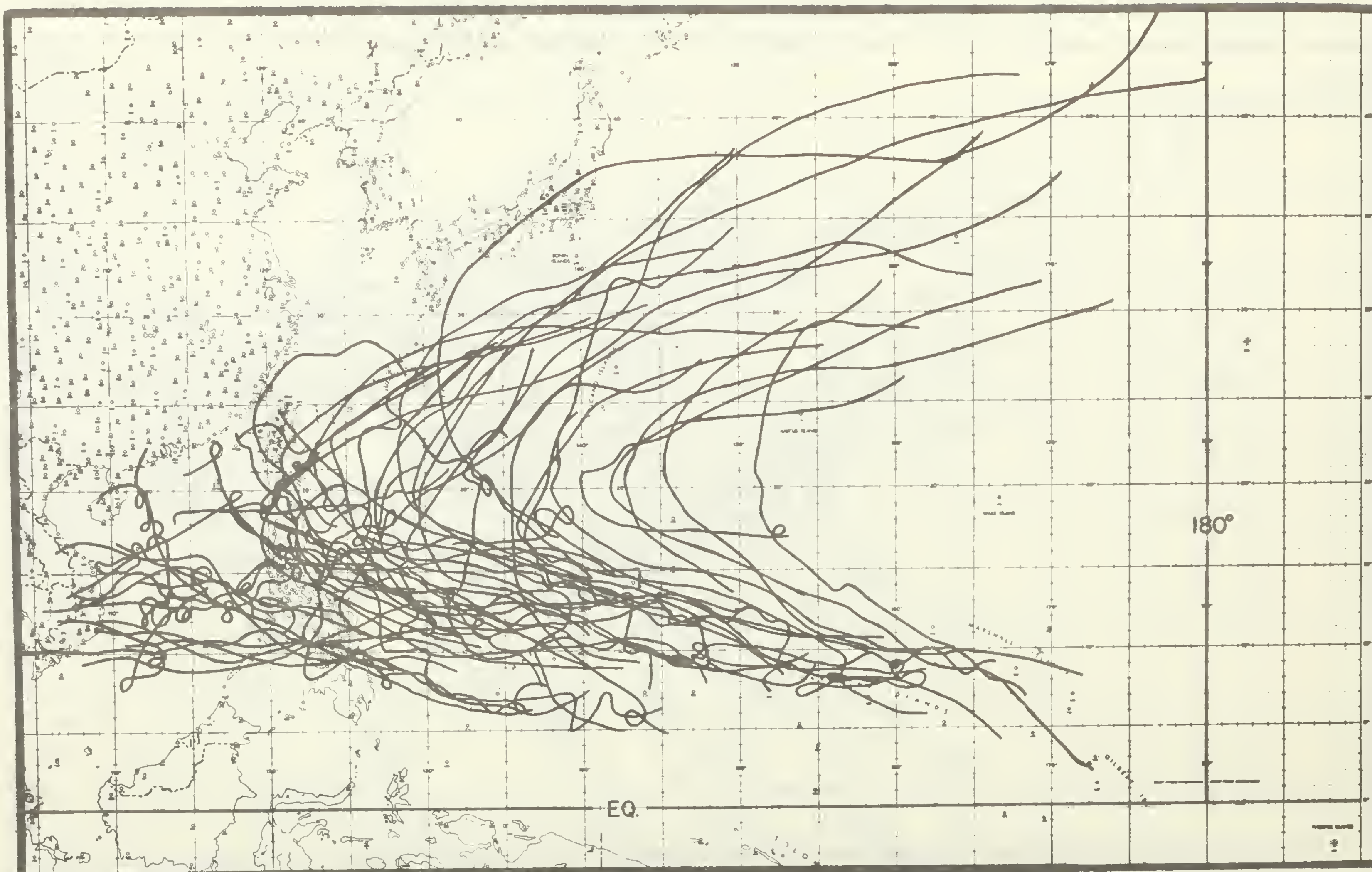


Figure B-13. November tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

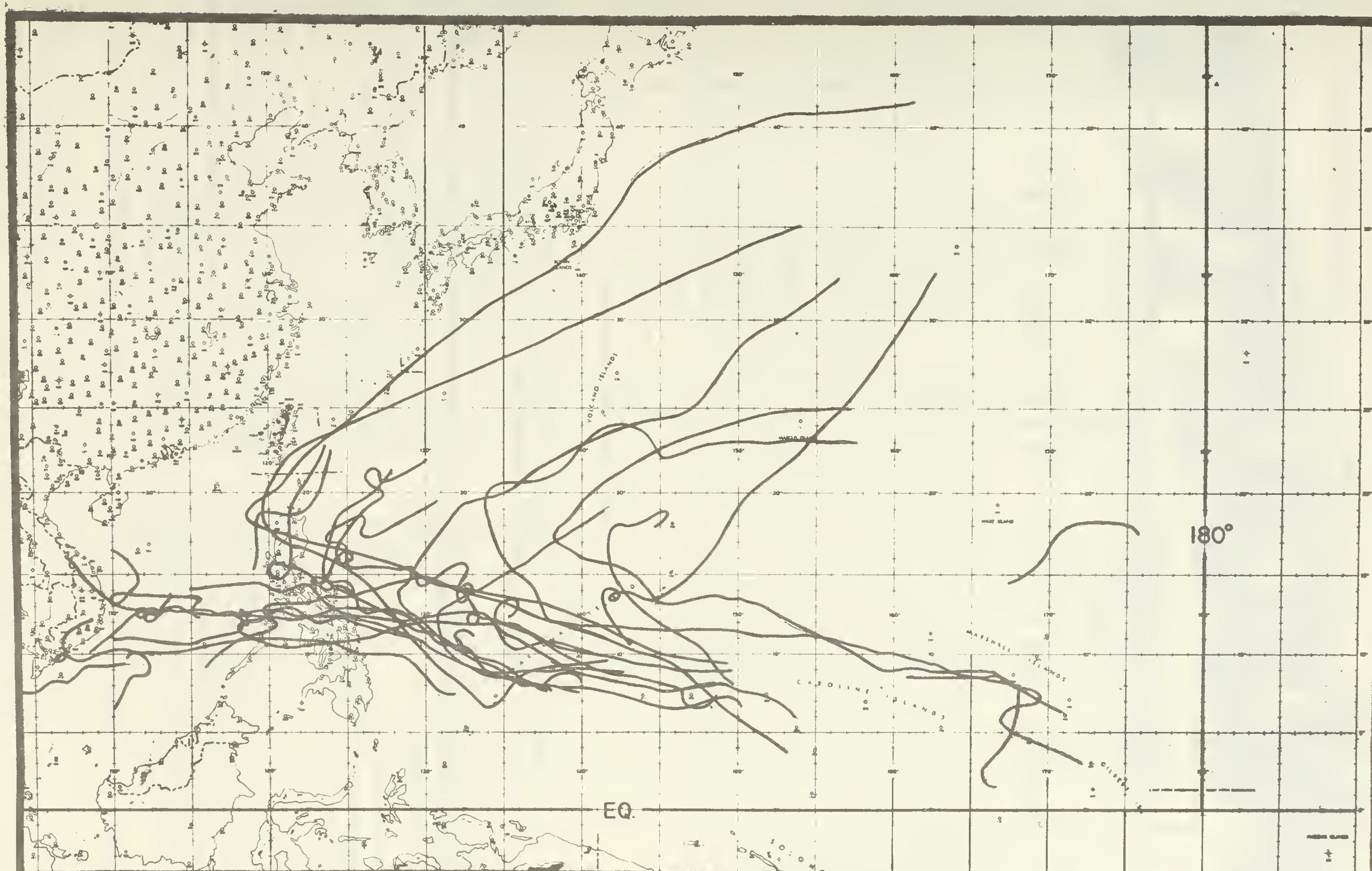


Figure B-14. December tracks of tropical cyclones which at some time were typhoons during the years 1946-1969. Tropical cyclones have been placed into monthly categories according to the median date of their existence.

APPENDIX C

Table C-1. Beaufort wind force scale conversion to knots (From, Lehr, et al, 1957).

Beaufort Number	Knots
0	0
1	1-3
2	4-6
3	7-10
4	11-16
5	17-21
6	22-27
7	28-33
8	34-40
9	41-47
10	48-55
11	56-63
12	64-71

Table C-2. Tropical cyclone classes

Class of Tropical Cyclone	Maximum sustained wind speed
Tropical Depression	Up to 33 knots (less than force 8 Beaufort)
Tropical Storm	34-47 knots (force 8-9 Beaufort)
Severe Tropical Storm	48-63 knots (force 10-11 Beaufort)
Typhoon	64 knots or more (force 12 Beaufort)

... The (Real) Live Adventures of

TYPHOON Joan and "Aggie" in the South China Sea

On 15-16 October 1970, USS Agerholm (DD-826) rode out Typhoon Joan in the South China Sea (chart at left). Joan was a typhoon of medium intensity, with winds of 100 knots near her center, 75 knots to 50 miles and 50 knots to 200 miles. At one point Agerholm passed within about 60 miles of Joan's center, in the navigable semicircle behind the storm. This narrative is being written only 15 hours after clearing the danger area. The ship is a shambles. As I toured her this morning I could only feel fortunate that we had come through. During the storm, when the worst which could happen did happen, we survived only because of prompt action and "blind" luck. There were mistakes made, an essential part of this narrative I make no effort to hide. Of utmost importance are the lessons learned, and in many instances learned again, and these I set forth in the hope that others may benefit from Aggie's experience. The experience was truly a frightening one, and as I look back, the issue was in doubt on several occasions. Agerholm apparently had nine lives and I am certain that she used a number of these during the 30-odd hours of the storm.

By CDR F. L. Taylor, USN
Commanding Officer, USS Agerholm (DD-826)

AGERHOLM was operating on 14 October as a screening destroyer for Task Group 77.6 in the Tonkin Gulf. Typhoon Joan had been reported for almost a week and had crossed the Philippines south of Manila, heading west across the South China Sea.[1] We completed refueling from the USS Wichita at midnight and were detached for an independent transit to Hong Kong. At about 0500 on the 15th some effects of weather were felt as the ship rounded the southern portion of Hainan Island. As we continued on a NE track during the forenoon the weather became increasingly rough, with wind and moderate seas from 020^0*, and an occasional large swell from about 060^0. This combination of sea and swell made it impossible to select a "good" course. Several swells crested on a height even with the bridge. One particularly large swell took the UHF can-type antenna off the top of Mount 51 and threatened to break out the pilot house windows.

Consequently, we reversed course along our original track. A review of weather warnings indicated this area to be an area of high seas for the next 12 hours. Our intent was to run back along Hainan Island until the unfavorable weather improved and then proceed again to Hong Kong. We did not, at this time, associate the heavy swells with Typhoon Joan, reported to be 350 miles to the southeast.

During this period I observed from the bridge a four-inch nylon line and a fire hose adrift on the foc'sle. These and other deck gear, including several large fenders from the unrep, were secured for sea. At some time during this period Agerholm lost the first of three inflatable lifeboats. Later in the afternoon the pad eye securing the outboard gripes on the motor whaleboat pulled out of the deck. A jury-rig jigger was attached and this held the boat secure throughout the storm.

At about 0130 on 16 October the ship was running southwest at 12 knots. Wind and seas continued unabated. More typhoon warnings were coming in, and

* All compass headings and bearings are given as true.

[1] See figure D-1.

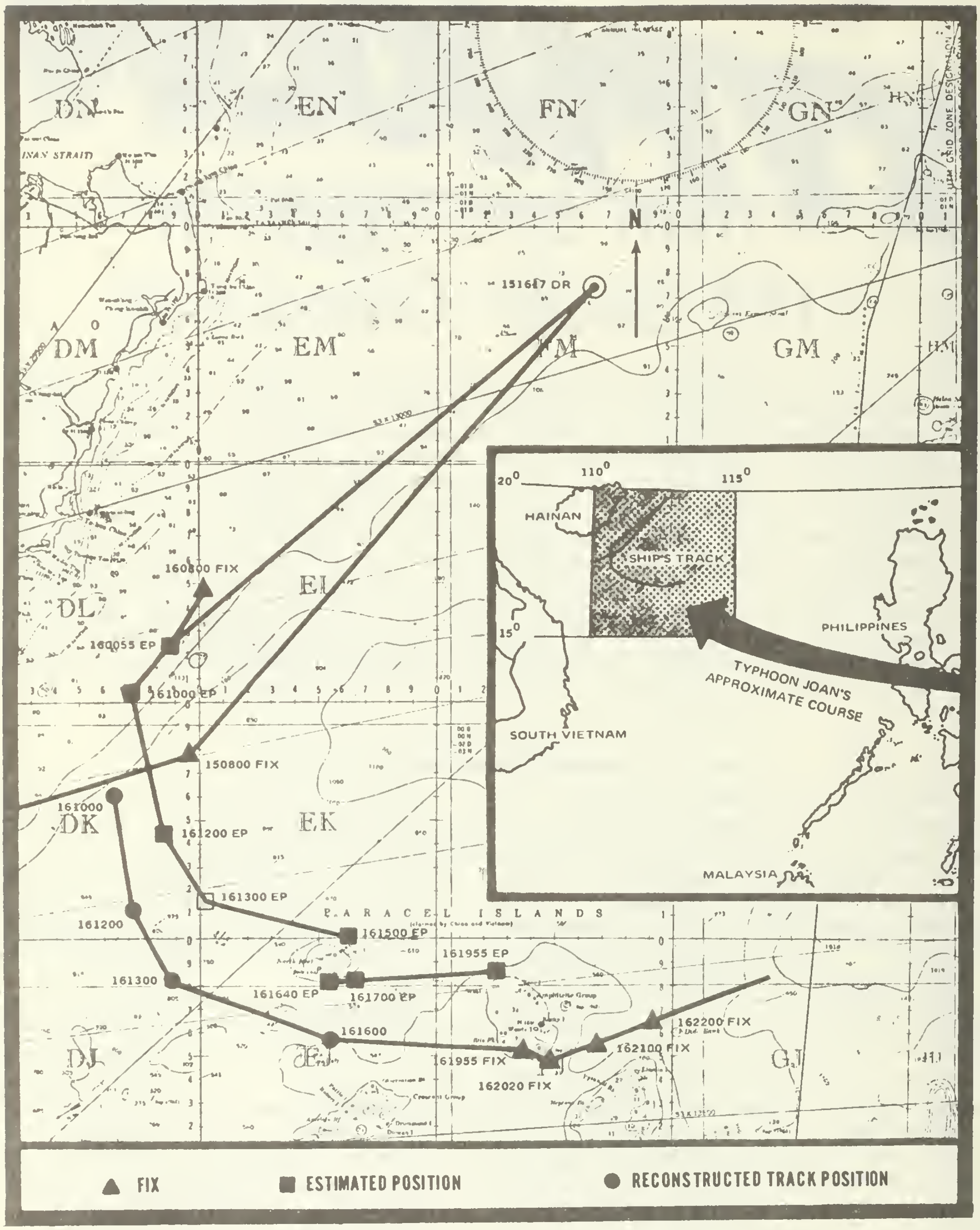


Figure D-1. Track of the USS AGERHOLM. (Note: At approximately 161515 water depth dropped to less than 500 fathoms. At 161640, partly because of the water depth readings, the Navigator revised the estimated position to the south.)

they indicated that Joan would go over land about 90 miles south of Danang. Rather than proceed south and closer to the possible path of the storm, the decision was made to turn about and lie to. I had some qualms about making the turn with the heavy sea state, but word was passed to stand by for heavy rolls and the turn was made without difficulty. Turns for seven knots were indicated and the ship rode fairly well, with a great deal of pitching. Radar held several peaks on Hainan Island and bearings on these showed the ship to be making no speed over the ground. At about this time we first associated the heavy ground swell with Typhoon Joan.

Throughout the rest of the night and for the next 20 hours I did not leave the pilot house. At about 0500 we received a report from the steering engineroom that there was "a lot of water" in the space. I had previously directed the boatswains mate of the watch to ensure that maximum watertight integrity be maintained in the steering engineroom. There was some initial difficulty in finding out what had happened, and more difficulty in getting response to remove the water. After a very trying period the engineer officer reported to the bridge that two large stanchions had been torn off the fantail leaving two gaping holes into the steering engineroom. I subsequently learned that the missing stanchions belonged to the large towing wire reel, which mysteriously departed the fantail, leaving all of the lifelines and snaking intact. Henceforth we kept three men in the steering engineroom to provide response to any casualty. The helm was in constant motion as the helmsman tried to maintain the ship's heading into the seas.

At sunrise we were greeted by an endless procession of huge seas sweeping by, most of them with foaming tops from the high wind. Shortly after sunrise the steering alarm sounded and the bridge lost steering control. While we desperately attempted to maintain our heading by engines, the after steering room reported a fire in the electrical junction box and a complete loss of power to after steering. Very fortunately the rudder was nearly amidships and the bridge was able to maintain heading by using the engines until manual steering could be set up. Once this was accomplished, steering was easier (but sluggish because of the time and effort involved in manual steering). The loss of power was determined to have been caused by water dripping through the vent to the main deck. The electrical junction box was jury-rigged and approximately one hour later the bridge was back in control. The power panel and the steering motors themselves were covered by canvas or plastic as protection against water.

By 0700 on the 16th we were pitching heavily and winds were gusting to 55 knots. Shortly thereafter the latest report on Joan indicated that the storm had turned and was proceeding northwest, directly toward us, at a distance of about 180 miles. There was no longer any doubt as to the source of our troubles.

The answer to our wondering which direction we should evade in was readily arrived at, since we could make no headway in any direction except downwind. Even this might put us across the path of the storm, in which case we might have to run ahead of the storm, up into the Gulf of Tonkin distinctly unfriendly territory.

The decision to turn the ship downwind was a distressing one to make because I felt she might roll over in the 40-foot seas, even though fully loaded with fuel. Visibility was extremely restricted because of flying spray and mist and it was impossible to pick an optimum time for the turn. All hands were advised of the situation and directed to keep lifejackets ready for immediate use. A flash message was then transmitted to operational commanders advising them of our intended action.

Shortly after 0800 on the 16th I directed the OOD to bring the ship about. I stood on the wing of the bridge trying to pick an optimum time. Wind and flying spray made it difficult to see and hear. The officer of the deck immediately put his rudder over and ordered full speed on the outboard screw and a standard bell on the inboard to provide good rudder control. Agerholm was caught by a 30-foot swell on the beam as she came smartly around. This large swell simply lifted the ship up and dropped her again, with little rolling motion. I was fully convinced by now that if several large steep swells caught her broadside during the turn she might roll over. Succeeding experience proved this lack of confidence in my "Fram I" to be unjustified.

As we steadied on a downwind course of about 220^0, there was a very noticeable air of relief on the bridge. The relative wind intensity dropped to about 35 knots with a corresponding drop in noise, and the ship appeared to be proceeding easily down the face of the large swells. Steering control was somewhat difficult and speed was increased to 15 knots. Immediately thereafter, Agerholm had her stern picked up by a large swell and she careened wildly off to the right to broach to in the trough of the swell, heeling over to port at an extreme angle which I estimated to be in excess of 50 degrees. One could have stepped out of the port pilot house door directly into the sea. I had a premonition of the end, but surprisingly enough she righted herself to an angle of about 30 degrees, where she was held by an estimated 60-knot wind. Somehow we were able to regain control; as I remember, it was through an initial burst of speed on both engines followed by a backing bell on the inboard (port) engine that we were able to

preclude the same incident from occurring again.

At this point I was thoroughly surprised at still having a ship, and my confidence had vastly increased. This confidence made my next 12 hours a little easier.

We quickly learned that with winds of 50 knots or more aft of the beam, the ship was extremely difficult to hold downwind. Each time the ship broached on a sea, or tried to, the wind would push the stern downwind, down the slope of the swell, and force the bow around to windward. The only effective means of preventing this was to use speed to provide rudder control. But here again, excessive speed could easily lead to "surfboarding" down a swell with a high probability of broaching. Through a nerve-racking trial and error period, we discovered that with the starboard engine ahead standard and the port engine ahead one-third we could easily maintain good helm control. We actually used this engine combination for most of the next 12 hours, until out of the storm's danger area.

Throughout the entire period we were attempting to keep the seas on the starboard quarter in order to open from the storm's center. Had the seas been on the opposite quarter, the opposite engine combination would have been equally effective.

Having found a workable means of maintaining our downwind heading, we settled into a routine to ride out the storm. As each large swell passed the ship she would settle into the following trough and appear to be making no way through the water. The succeeding swell would lift the stern and at the same time the bow would bury itself in the trough, with only the jackstaff pedestal remaining visible forward of Mount 51.

As the ship moved higher on the face of the approaching sea she would slowly pick up forward motion, her progress being marked by the jackstaff proceeding through the white water like a submarine periscope, until finally the bow would surface and the ship would drop over the crest into another trough. During each of these cycles Agerholm's speed would appear to increase from zero to an estimated 15 knots.

It became increasingly apparent that we were now slaves of the storm, being committed to run downwind in an attempt to open the storm center. I spent much of the early downwind period watching huge swells come up astern and coaching the OOD right or left a little to minimize the tendency for these swells to broach the ship. The seas were very large, steep and confused, indicating that we were quite close to the storm center. Large swells routinely came cresting by at a level above the pilot house. Occasionally seas on opposing courses would come together, ejecting gysers 60 feet or more into the air. A look in any direction gave the appearance of a maelstrom in which no ship could survive, and we were in the middle.

Since reversing course at 0800 we had had no means of navigation and an accurate DR track was almost impossible to plot. By rule of thumb (face the wind and the storm center lies 115 degrees to the right) the storm center was farther north than reported and probably quite close. This estimate was later found to be highly accurate. Of immediate concern was the fact that the wind was slowly backing, thus Agerholm's course was continually shifting to the south and east. We knew that the Paracel Islands were some 60 miles to the southeast. Avoiding these became one of my primary concerns. With the standard/one-third engine combination I assumed our speed to be about eight knots. As a precaution I calculated our approach to the Paracels at 12 knots and maintained a close watch on the depth-sounder. Radar was useless and visibility at all times was less than one mile. At about 1430, somewhat sooner than I had anticipated, the fathometer gave an indication of shoaling water which I correctly assumed to be the Paracel Group. I further assumed, incorrectly, that this would be the North Reef, but I had no idea of where the island lay. Visibility was extremely restricted and every large swell periodically broke into a giant surfline. I conned the ship past this first reef by fathometer information with a distinctly sick feeling in the pit of my stomach, straining to see anything that might be surf, with the intention of immediately bringing the ship about in the event I could identify anything, or if the fathometer indicated rapidly shoaling water. The fact that I could probably make no headway, even if I should successfully make the turn, remained in my mind.

Soon the water deepened again and I felt security in the knowledge that I thought I knew where we were and when to expect the last remaining island, and we adjusted the ship's head to the left to pass clear. Several hours later the fathometer again indicated shoaling water. We had been proceeding downwind on a course of 100^0, plus or minus 10 degrees. I assumed that this would be the Amphitrite Group and that Agerholm would pass just to the north. Consequently our heading was changed to 070^0 which placed the wind and seas about 30 degrees on the port quarter, at a point where almost full right rudder was required to prevent broaching. On this heading the wind heeled the ship over to a constant 20-30 degrees, which increased each time a following sea passed. Fathometer indications were consistent with where I thought the ship to be, and it was with a distinct feeling of relief that we passed this island and again entered deep water.

By dark, Agerholm was riding well, having crossed

behind the storm center at a range estimated to have been 60 miles. We were able to open the storm on a course of 090°, although seas were still mountainous and the true wind remained between 65-80 knots. At about 1930 on the 16th we had a radar contact at 077°, 16 miles. After an evaluation that the contact had no course or speed, someone wiser than I compared our fathometer reading with the reciprocal bearing and range from Woody Island in the Amphitrite Island Group. The depth compared perfectly and as we approached Woody Island the comparison proved correct. Another course change to 110° was made to pass safely. Lincoln Island was detected and passed shortly thereafter.

Reconstruction based upon these final sightings indicated that we had been making a fairly steady 17 knots, running with the seas on the standard/one-third combination. This was double what we believed our speed to be, and of course put the ship well south of our DR position and into the Paracel Group. Laying out the ship's track in reverse indicated that we had not, in fact, passed North Reef or the Amphitrite Islands close aboard, but that we were obtaining soundings in the relatively shallow waters to the south.

Maneuvering was still restricted in that we could not turn more than 30 degrees off the downwind course. The wind, however, dropped occasionally to 55 knots and for the first time the barometer increased, having dropped some .80 of an inch over the last day and a half to a low of 28.80. By 2100 on the 16th the ship was riding easily, relative wind was between 35 and 45 knots, backing, with the seas more stable. We were thus able to maintain our desired 090° heading. I left the bridge for the first time in almost 24 hours.

As I look back, the wind was the predominant factor with which we had to contend. Seas were generally mountainous but when the true wind speed remained between 50-60 knots it was not too difficult running downwind. Periodically, however, the wind would increase to 70-80 knots. During these periods the seas would quickly increase in height and appear to run in several directions, cresting white foam continuously. Visibility decreased radically and noise intensity increased. Maintaining a downwind heading became increasingly difficult, and the ship would be boarded by successive seas. One could hear and feel each swell as it rumbled from aft along the ship. We were surrounded by white water and flying spray The total effect was frightening and the question foremost in everyone's mind was "When will this end?" or "How much longer can we take it?" By comparison, when the wind dropped to 40-50 knots it was almost like a Sunday afternoon at the park.

Ship's routine while in the storm was, of course, greatly disrupted. Help was needed everywhere. Spaces and passageways had to be dewatered, loose equipment had to be secured and extra watches stood. It was interesting to observe that as ship motion became increasingly violent, seasickness all but disappeared. All hands were fighting to save the ship.

Repair personnel in all departments had little sleep in two days. Electrical fires were epidemic. Water was coming into the ship at some new place every hour, and vital electrical and electronic equipment had to be watched around the clock. Under these conditions, three and even two section watches became impractical.

No attempt was even made to serve complete meals. Sandwiches and simple but hot entrees that could be eaten on the run or carried off to the working spaces in paper plates and cups proved most acceptable.

Early in the storm even minor rolls were accompanied by crashing, banging and, frequently, loud talking. This diminished with successively more severe rolls until the 50 degree plus roll. After that, each roll was accompanied by an unusual silence, since everything had found a place, although not necessarily the right place.

Agerholm today is undoubtedly the best secured ship in the fleet, and, at the moment, also the messiest. No one in this crew will ever need to have explained the necessity of "securing for sea."

Lessons Learned

1. In preparing a ship for sea, all topside equipment must be securely stowed and lashed down. Once heavy weather is encountered it is either too late or extremely hazardous. In particular, fire hoses should be secured in their stowages so that the bitter end cannot come adrift and subsequently drag out the rest of the hose.

2. Maintaining steering control is of utmost importance in heavy weather. While the tearing of holes in the deck above the steering engineroom could not be anticipated it is a common problem to have *both* the scuttle and the air vent leak due to poor maintenance. These items need routine attention when the ship is in port. The scuttle is a particular problem because on the 2250 Class, and probably others, the electrical junction box is almost directly under it.

It is also highly advisable to have additional people, one of whom is an electrician, standing by in the steering engineroom to assist in the event of a casualty during heavy weather conditions.

3. When turning the ship under extreme conditions of wind and sea, use full or flank speed on the outboard engine and standard on the inboard, or some similar combination which will put speed on the ship. Do NOT back the inboard engine. The result of backing will be to make the ship wallow in her turn and cause the rudder to be useless.

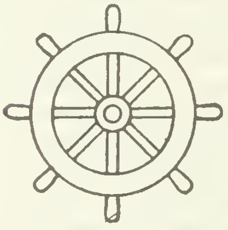
4. With winds of over 50 knots acting on the ship aft of the beam she will have a very strong tendency to broach into the wind. I believe this characteristic to be accentuated by, if not entirely due to, the Dash hangar on the Frams. Since speed was required to maintain good rudder control, and excessive speed would lead to "surfboarding," a combination of one engine ahead standard with the other ahead one-third offered good control and enabled us to keep the seas on the quarter of the standard engine in order to open from the storm center.

5. Each commander, when committing himself to a course of action to avoid a storm, should recognize that he may, in fact, remain committed to that course of action with no alternatives. In Agerholm's case when the decision was made to run downwind the only possible alternative would have been to run to the right, up into the Tonkin Gulf. I believe now that the very small latitude for maneuvering would have precluded even this. I did not consider that I would be forced to steam blindly through the Paracel Islands, nor did I realize that I would be close enough to the storm center to render radar and visual assistance useless. The awareness that in a severe storm you will have little control over the ship and little or no position information should weigh heavily on the course-of-action decision.

Major Equipment Lost

three nylon mooring lines (one 5", two 4")
three Mk-5 inflatable lifeboats
six liferings
35 kapok lifejackets
six fire nozzles
five lengths of 2½" firehose
10 lengths of 1½" firehose (Note 1)
three 10-foot applicators
three P-250 gasoline cans
two nylon boat falls (4") – (badly chafed, requiring replacement)

Note 1. In several instances a lost firehose was connected to a deck riser and the entire riser (fireplug) was torn out of the deck. ■



APPENDIX E

The following figures, E-1 and E-2, represent the estimated resultant speed-of-advance of a ship in a given sea condition. The original relationships were based on data of speed versus sea state, obtained from many ships by James (1957), and they should not be regarded as truly representative of any particular ship (Nagle, 1972).

For example, from Figure E-1, for a ship making 15 kt with waves of 16 ft approaching from 030° (relative to the ship's heading) one can expect the speed-of-advance to be slowed to about 9 kt. Twenty-foot seas, under the same condition, would result in a speed-of-advance of slightly less than 6 kt. However, it is emphasized that these figures are averages and the true values will vary slightly from ship to ship.

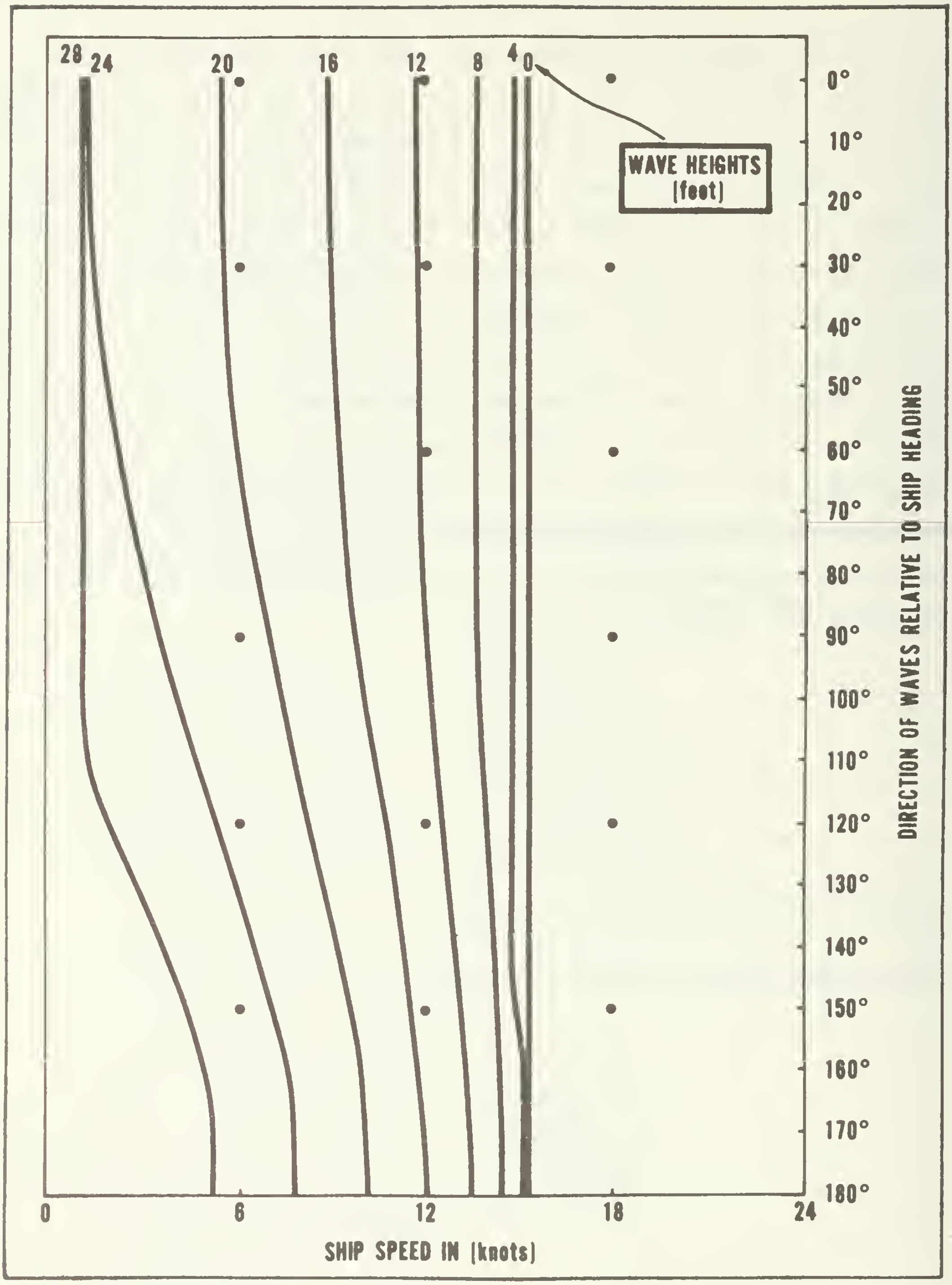


Figure E-1. Ship speed as a function of wave height and wave direction relative to ship's heading (15-kt ship). (From Nagle, 1972).

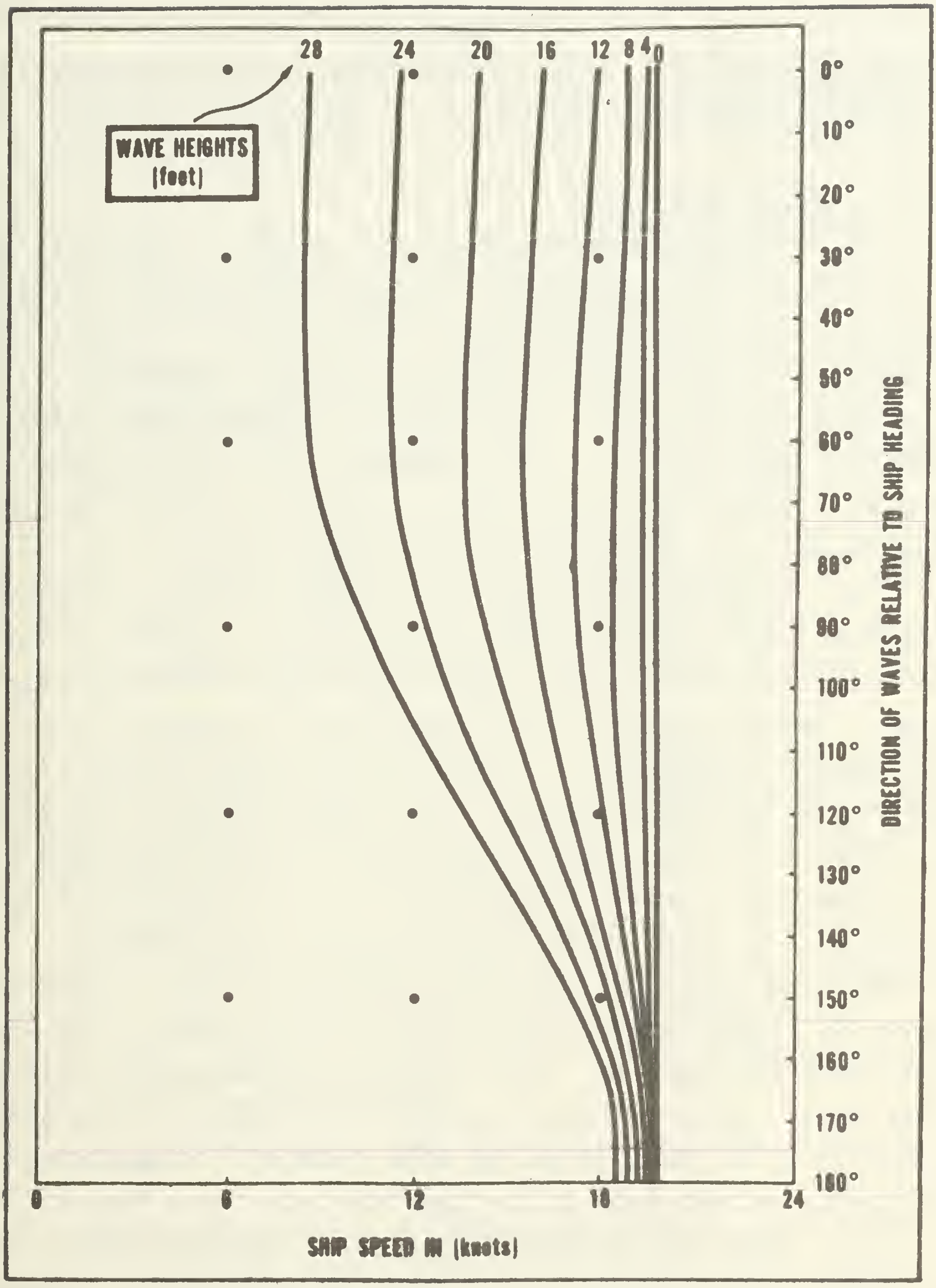


Figure E-2. Ship speed as a function of wave height and wave direction relative to ship's heading (20-kt ship). (From Nagle, 1972.)

APPENDIX F

ANNEX W

HEAVY WEATHER PLAN (From COMSEVENTHFLTINST 5000.1H SOPA Instructions Hong Kong B. C. C, dated 29 Feb 1972)

1. TYPHOON READINESS

a. COMSEVENTHFLT OPORD 201, ANNEX W, furnishes pertinent information concerning Typhoon Readiness and establishes special reporting requirements for ships in a severe weather situation. The Typhoon Doctrine for the USNAVPHIL area, including Hong Kong, is contained in COMUSNAVPHIL OPORD 201, ANNEX W, Appendix II. SOPA (ADMIN) will make the ships present report required by that directive, but will modify the format and report only U. S. Navy ships.

b. FLEWEACEN/JTWC Guam is responsible for providing tropical storm warnings for all typhoons, tropical storms and tropical depressions occurring west of 180 degrees longitude. These warnings are transmitted via appropriate fleet and general broadcasts. Storm warnings are also broadcast on Hong Kong Harbor Common. The Hong Kong Royal Observatory located in Kowloon issues warnings when the Hong Kong area is threatened, using Signal Nos. 1, 3, 5 (8 NW) 6 (8 SW), 7 (8NE), 8 (8 SE), 9, and 10 and strong wind signals. These signals and their meanings are found in Tab A to Appendix II, Annex W, COMSEVENTHFLT OPORD 201 and the Appendix to Hong Kong General Order No. 112, issued by Commodore-in-Charge, Hong Kong. Relevant sections of the latter will be distributed to U. S. Navy ships by SOPA (ADMIN). Commanding Officers are required to be familiar with this order.

c. Upon the hoisting of a local warning signal, No. 1 or higher, SOPA and all U. S. Navy ships present in Hong Kong will be guided by the provisions of Hong Kong General Order No. 0150 and are expected to conform to the recommendations of Commodore-in-Charge, Hong Kong, and to depart in

a timely and orderly fashion if requested. Commanding officers should not hesitate to request permission from SOPA to get underway prior to a general sortie, if such action is deemed expedient. Because of the somewhat reduced number of Naval buoys now maintained at Hong Kong, it is probable that all buoys suitable for use in typhoon weather will be required for British Naval ships. In these circumstances, the timely vacating of the Naval buoys upon receipt of instructions from the Commodore-in-Charge, Hong Kong is essential.

d. During the typhoon season (15 May through 31 October) ships are to moor to buoys with two bridles (normally one chain and one spring lay or wire rope) and have engineering plants on four hours notice. A ship which anticipates a condition that would prevent getting underway on four hours notice during typhoon season, or eight hours notice at other times, will report by message to SOPA and SOPA (ADMIN) giving reason and expected duration of the existing conditions of readiness.

e. Ships present in Hong Kong will immediately notify SOPA and SOPA (ADMIN) when disabled. SOPA (ADMIN) will keep Commodore-in-Charge, Hong Kong advised in order that he might make suitable provisions for typhoon berths.

f. Commodore-in-Charge, Hong Kong issues a "Daily State" which contains typhoon berth assignments for the port of Hong Kong. This "Daily State" is distributed to all U. S. Navy ships present by guard mail. HMS TAMAR maintains a current list of typhoon buoys.

g. As a result of a 1966 evaluation of Hong Kong as a typhoon haven, it is considered that Hong Kong is not a suitable typhoon haven for SEVENTH Fleet units. The typhoon instructions for Hong Kong provide, in general, for putting to sea or remaining in port. For ships that remain in port, either a typhoon buoy or an anchorage to the west or southwest of Stonecutters Island may be assigned as a typhoon

berth. Although the decision of SOPA will govern in each case, it is considered that putting to sea is the preferred alternative. All portions of paragraph 6 of Appendix II to Annex W of COMSEVENTHFLT OPORD 201 should be weighed carefully before a decision is made to remain in port in Hong Kong during a typhoon. All sorties from Hong Kong for typhoon evasion should be made early due to limited sea room in the northern portion of the South China Seas.

h. Ships under sortie for temporary typhoon evacuation will guard special circuits as required by paragraph 4(b)(2), Appendix IX, Annex F, COMSEVENTHFLT OPORD 201.

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Tropical Cyclone Evasions
Measure of a Harbor
Typhoon ROSE
Typhoon WANDA

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study evaluates the harbor of Hong Kong as a typhoon haven. Characteristics of the harbor under tropical cyclone conditions, including topographical effects on the wind, storm surge and reliability of moorings and anchorages are discussed and highlighted by two case studies (Typhoon ROSE, August 1971 and Typhoon WANDA, September 1962). Problem areas to be considered if remaining in port and possible evasion procedures

for ships sailing from the port are examined for tropical cyclones approaching from various directions. Tropical cyclone tracks for 87 years of data (1884-1970) for the western North Pacific Ocean are examined in order to determine the probability of threat to the port of Hong Kong. Results suggest early sortie action under threatening conditions by all Fleet units capable of evasion at sea.

Thesis 145778
M3856 Mautner
c.1 An evaluation of Hong
Kong Harbor as a typhoon
haven.